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STATE OF WASTE MANAGEMENT PRACTICES ON FISHING VESSELS IN THE MEDITERRANEAN SEA: REVIEW OF COMMON SOURCES, REGULATORY FRAMEWORKS, AND PORT WASTE RECEPTION FACILITIES

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List of acronyms

ABNJ	Marine Areas Beyond National Jurisdiction
ADV	Abandoned and derelict vessel
AF	antifouling
AIS	Automatic Identification System
ALDFG	Abandoned, lost or otherwise discarded fishing gear
AUV	Autonomous Underwater Vehicle
CBD	Convention on Biological Diversity
DCRF	GFCM Data Collection Reference Framework
DFG	Derelict Fishing Gear
DWT	Deadweight Ton
EPR	Extended Producer Responsibility
EU	European Union
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organisation
FFL	Fishing for Litter
FRP	Fibre-Reinforced Plastic
GEF	Global Environment Facility
GES	Good Environmental Status
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GFCM	General Fisheries Commission for the Mediterranean
GGGI	Global Ghost Gear Initiative
GPML	Global Partnership on Marine Litter
GPS	Global Positioning System
GT	Gross Tonnage
HELCOM	Helsinki Commission
ICC	International Coastal Clean-up
IMAP	Integrated Monitoring and Assessment Programme
IMO	International Maritime Organization
IOC	International Oceanographic Commission
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated fishing
LCA	Life Cycle Assessment
LSF:	Large-Scale Fisheries
MAP	Mediterranean Action Plan
MARPOL	International Convention for the Prevention of Pollution from Ships
MEDITS	Mediterranean International Trawl Survey
MEDPOL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean
MEPC	Marine Environment Protection Committee
MIO-ECSDE	Mediterranean Information Office for Environment, Culture and Sustainable Development
ML	marine litter
MSFD	Marine Strategy Framework Directive
NEAFC	North East Atlantic Fisheries Commission
NGO	Non-Governmental Organization
NSF systems	No-Special-Fee systems
PRF	Port Reception Facilities
SPA/RAC	Regional Activity Center for Specially Protected Areas

REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RFMO	Regional Fisheries Management Organization
ROV	Remotely Operated Vehicle
SSF	Small-Scale Fisheries
TED	Turtle Excluder Device
TRL	Technology Readiness Level
TV	Threshold Value
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFSA	United Nations Fish Stocks Agreement
UV	Ultraviolet
WCPFC	Western and Central Pacific Fisheries Commission

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About the author

François Galgani is a senior scientist at Institut français de recherche pour l'exploitation de la mer (Ifremer, France), specializing in marine environmental sciences and pollution in the Mediterranean Sea. Over the course of his career, he has worked in several renowned

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Dr. Galgani has actively contributed to major global initiatives, including those led by the G7, G20, and the UNEA Science Advisory Committee on Plastic Pollution. From 2019 to 2021, he served on the Board of the EU Horizon Europe Mission "Restore our Oceans and Waters."

He is the author of more than 200 scientific publications and currently serves as Editor-in-Chief of the international journal Marine Pollution Bulletin. Additionally, he is responsible for the "Marine Litter" chapter of the United Nations World Ocean Assessment (WOA II in 2021 and WOA III scheduled for 2025).

Foreword

The Mediterranean supports ancient fisheries alongside diverse industrial, semi-industrial, and small-scale operations that exploit its rich biodiversity. Unlike other regions, it lacks large mono-specific fisheries, relying instead on a variety of benthic and pelagic stocks, including mollusks and crustaceans. Due to its semi-enclosed nature, regional cooperation among riparian states is essential for sustainable management, ensuring a balance between preserving marine biodiversity and meeting the needs of fishing communities. Despite being overshadowed by emerging sectors such as tourism and oil exploration, the fisheries sector remains vital for employment, nutrition, and the sustenance of coastal communities. With increasing anthropogenic pressures, there is a growing need for science-based, ecosystem approaches to fisheries management.

The FishEBM MED project aims to support the recovery and sustainable use of selected commercially important marine resources by strengthening the capacity of Mediterranean countries to manage fisheries. This includes the application of ecosystem-based fisheries management (EBFM) tools tools as part of their blue economy development pathway. The FishEBM MED is supported by the Global Environment Facility (GEF) and is a collaborative effort led by the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP). Its execution is facilitated by the General Fisheries Commission for the Mediterranean (GFCM) and the Mediterranean Action Plan (MAP) under the Barcelona Convention, through the Specially Protected Areas Regional Activity Centre (SPA/RAC).

The project is implemented in Albania, Algeria, Bosnia and Herzegovina, Lebanon, Libya, Montenegro, Morocco, Tunisia, and Türkiye. It aligns with the Post-2020 Strategic Action Programme for the Conservation of Biological Diversity in the Mediterranean (SAPBIO) and the GFCM’s 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea.

The project seeks to achieve the following key objectives:

Enhancing capacity for sustainable fisheries management in line with SAPBIO’s biodiversity conservation goals.

Integrating advanced monitoring technologies to address illegal, unreported, and unregulated (IUU) fishing, a priority of the GFCM 2030 strategy.

Implementing ecosystem-based management tools as advocated by both SAPBIO and the GFCM to ensure long-term sustainability.

Developing innovative blue economy solutions that align with the objectives of both frameworks to promote sustainable economic development.

Sharing knowledge and best practices to foster collaboration, learning, and regional cooperation, as emphasized in SAPBIO and GFCM strategies.

Under Component 3 of the FishEBM MED project, titled “Integrated Ecosystem-Based Management Tools and Ecosystem Approach to Biodiversity Protection and Sustainable Fisheries,” the focus is on identifying measures to mitigate the negative effects of potential stressors on biodiversity.

The objective of this report is to review existing solid waste management practices on board fishing vessels in the Mediterranean and globally. This includes identifying common sources of solid waste, evaluating the effectiveness of current regulations and waste management systems at fishing port facilities, and highlighting gaps and areas for improvement. The findings aim to inform the development of comprehensive guidelines to reduce and manage solid waste discharge from fishing vessels in the Mediterranean region.

Executive summary

The Mediterranean Sea, renowned for its rich biodiversity and cultural heritage, faces increasing threats from marine litter, particularly from fishing activities. As a semi-enclosed sea, home to ancient fishing traditions and diverse fishing practices, it supports a complex ecosystem of benthic and pelagic species. Its fisheries are vital for regional food security, livelihoods, and socio-economic stability. However, its unique geography and role as a hub for global tourism and maritime transport intensify pressures on marine resources, leading to significant environmental challenges.

Marine litter is a significant contributor to the degradation of Mediterranean ecosystems. In addition to litter from fishing operations, plastic from grey waters, microplastics from paints and coatings, and Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) pose persistent threats. Materials such as nets, ropes, and traps can remain in the marine environment for decades, continuing to harm marine life, disrupt habitats, and exacerbate biodiversity loss. Beyond ecological consequences, marine litter undermines the socio-economic foundations of coastal communities that rely on fisheries and tourism. Addressing this issue requires a concerted effort to understand the nature, sources, and impacts of fishing vessel waste and to implement effective management strategies.

The Mediterranean fishing fleet, comprising over 73,000 vessels, is predominantly small-scale and artisanal, yet it generates waste. Plastic litter, including from ALDFG, dominates the seabed, accounting for over 95% of all recorded debris. The semi-enclosed nature of the Mediterranean exacerbates litter accumulation, particularly in coastal regions, enclosed bays, and areas with low circulation. The role of fisheries in marine pollution must be seen in a balanced and harmonized way. fishers are not the primary contributors to plastic pollution at sea. Furthermore, the economic impact of marine litter on the fishing sector requires stronger emphasis, as marine litter is accidentally captured during fishing operations, leading to damaged gear and increased operational costs.

Efforts to monitor and manage marine litter face numerous challenges. Seafloor litter assessments, for example, are hampered by deep-sea inaccessibility and monitoring methodologies variability. Trawl surveys, while offering long-term data collection, may underestimate litter due to gear limitations. Advanced underwater imaging technologies, such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs), enable detailed observation but remain expensive and complex. Emerging technologies, including hyperspectral imaging and machine learning, are enhancing litter detection and classification but require further development for large-scale application.

Studies on ALDFG have highlighted the localized and regional impacts of fishing gear waste. Areas such as the Tunisian-Sicilian channel and the northern Adriatic exhibit some of the highest densities of fishing-related debris, reflecting intensive fishing activity and specific gear types used. For instance, fish aggregating devices dominate litter in the southern Tunisian-Sicilian channel, while ropes and lines are more prevalent in the northern part. Similarly, mussel and oyster socks constitute up to 30% of fishing-related waste in the northern Adriatic. These findings underscore the link between local fishing practices and the type and quantity of waste found on the seabed.

Data scarcity remains a major challenge, particularly for small-scale fisheries. Limited standardized methodologies across Mediterranean countries further complicate marine litter assessments. Despite these challenges, initiatives such as "Fishing for Litter" have shown promise in promoting waste recovery and fostering regional collaboration. Programs incentivizing fishers to retrieve lost gear and bring marine litter ashore have gained traction as practical and cost-effective solutions.

Regulatory frameworks for waste management from fishing vessels remain fragmented and inconsistently enforced across the Mediterranean. Limited port reception facilities and on-board waste management exacerbate the issue.

Preventing and managing marine litter from fishing activities also necessitates investment in innovative technologies and infrastructure. Gear marking programs, retrieval initiatives, and recycling systems can significantly reduce ALDFG prevalence. Advanced monitoring tools, such as acoustic imaging systems and hyperspectral cameras, offer now opportunities to improve data collection and litter classification. Integrating these technologies into existing monitoring frameworks will enable more accurate assessments of litter distribution and its ecological impacts.

Waste from fishing vessels, especially ALDFG, significantly impacts marine ecosystems, biodiversity, and coastal economies. ALDFG contributes to ghost fishing, which ensnares marine life, damages habitats, and spreads invasive species. ALDFG also harms wildlife through entanglement and ingestion, leading to injuries, reduced survival rates, and ecological imbalances. The socio-economic effects include financial burdens on coastal communities and losses in tourism and ecosystem services. Efforts to retrieve ALDFG can exacerbate habitat damage, while the breakdown of fishing materials introduces microplastics into marine food webs. This highlights the urgent need for sustainable fishing practices and effective mitigation strategies to address ALDFG's widespread impacts.

Strategies to address waste from fishing vessels include prevention through improved gear design, marking, recovery programs, and recycling initiatives. Prevention measures focus on regulatory, educational, and technological approaches, such as using durable, biodegradable materials and improving operational practices to minimize gear loss. Recovery efforts, including Fishing for Litter programs and advanced retrieval technologies, mitigate environmental impacts. Effective port reception facilities (PRFs) with accessible and incentivized systems are essential for waste management, especially in regions like the Mediterranean and initiatives to convert synthetic fishing gear into reusable products promote sustainability despite technical challenges and financial viability. Two key instruments of the regional framework of the General Fisheries Commission for the Mediterranean (GFCM) are parts of the management strategies: Resolution GFCM/44/2021/14 on abandoned, lost or discarded fishing gear, and Recommendation GFCM/42/2018/11 on regional fishing gear marking are essential for improving traceability, accountability, and prevention of gear loss at sea. More generally, international frameworks like MARPOL, the Regional Action Plan on marine litter-from the Barcelona Convention, other regional initiatives, and harmonized practices are critical to improving PRF operations and addressing resource disparities. Technological innovations, public-private partnerships, and regional cooperation are essential for advancing waste management, and supporting sustainable fisheries.

Global efforts to tackle waste from fishing vessels involve international agreements, regional frameworks, and collaborative initiatives targeting prevention, recovery, recycling, and awareness. Key initiatives include the MARPOL Convention, which prohibits plastic discharges and mandates port reception facilities (PRFs); the Barcelona convention and its regional Action Plan, the FAO to enhance traceability and accountability; and the Global Ghost Gear Initiative, focusing on practical solutions like gear recovery and biodegradable materials. Programs such as GloLitter Partnerships (IMO & FAO) and Fishing for Litter engage stakeholders in waste management, while regional projects (e.g. BlueMed, Plastic Busters) focus on innovative waste recycling and gear recovery. Port reception facilities play a pivotal role, supported by initiatives like the North European MARELITT Project and the EU's Port Reception Facilities Directive, which harmonize waste management practices and encourage recycling. Public-private partnerships and technological advancements, such as GPS-enabled gear tracking, enhance global efforts. Legal frameworks, including UNCLOS, MARPOL, and regional agreements, provide the regulatory backbone for managing ALDFG. However, challenges in enforcement, resource disparities, and limited infrastructure remain significant barriers, emphasizing the need for international cooperation, localized strategies, and sustained investment to ensure long-term sustainability.

In the Mediterranean, especially in the Southern Mediterranean, Small-Scale and artisanal Fisheries dominate but lack structured monitoring and reporting systems, creating significant data gaps on waste from fishing vessels. Research is needed to better define their sub regional sources, amounts, distribution, and impacts. Resource constraints hinder data collection, hotspot mapping, and the implementation of advanced localization and recovery technologies. Collaborative regional studies (e.g. the Marine Litter Med project) can help bridge these gaps by focusing on hotspots, environmental impacts, and targeted mitigation strategies, such as eco-friendly gear and recycling methods. Port Reception Facilities (PRFs) are essential for managing fishing waste. Effective PRFs should include pre-treatment facilities, recycling pathways, and cost recovery mechanisms, aligning with the "polluter pays" principle. Tailored regional strategies, targeting regional and local practices, international collaboration, investments in infrastructure, and advanced technologies are crucial for addressing ALDFG and more generally waste from fishing vessels, promoting sustainable waste management in the Mediterranean.

In fine, the Mediterranean's ecological importance and the socio-economic reliance of its communities on marine resources demand urgent action to address the issue of marine litter. Harmonized regulatory frameworks, enhanced monitoring capabilities, and stakeholder engagement are essential for mitigating the environmental and economic impacts of fishing vessel waste. The findings from this report highlight the need for collaborative, region-wide efforts to implement sustainable management practices and innovative solutions that ensure the resilience of Mediterranean ecosystems and the livelihoods of coastal communities. By prioritizing prevention, recovery, and regulation, stakeholders can safeguard the Mediterranean Sea for future generations.

1 INTRODUCTION

The Mediterranean Sea is heavily impacted by numerous anthropogenic pressures. The Mediterranean basin is the world's leading tourist destination, hosting more than 25% of global tourism. It is home to approximately 350 million people, representing about 7% of the global population, and 30% of global maritime transport passes through this region (UNEP MAP, 2015). In addition, this basin is nearly enclosed, with minimal exchanges at Gibraltar and through the Suez Canal. Beyond recurrent local pollution, numerous impacts on biodiversity have been reported, including over-tourism, habitat loss, the emergence of invasive species, and unsustainable fishing practices in certain areas. Among the contributor to this problem is the unintentional or unmanaged release of waste from fishing vessels. This issue raises urgent questions about sustainable practices, regulatory measures, and international cooperation to mitigate the effects of marine litter on ecosystems, economies, and coastal communities.

The role of fisheries in marine pollution must be presented in a balanced and harmonized way. While fishing activities—particularly the loss or abandonment of gear—are a recognized source of marine litter, fishers are not the primary contributors to plastic pollution at sea. The largest proportion of marine litter, including plastics, originates from land-based sources such as urban runoff, inadequate waste management, and riverine inputs. Singling out the fisheries sector without acknowledging this broader context may unfairly stigmatize coastal communities whose livelihoods depend on sustainable marine resources. At the same time, the fishing sector itself is heavily impacted by marine litter, which poses serious operational and economic burdens. Fishers frequently report the accidental capture of debris during fishing operations, particularly on the seafloor, which can damage fishing gear, reduce catch efficiency, and require costly repairs or gear replacement. The presence of litter may also lead to longer fishing times, increased fuel use, and potential safety hazards. In the Mediterranean Sea, these consequences are especially acute for small-scale and artisanal fisheries, which operate on tight margins and often lack the capacity to absorb additional operational costs. Fishing-related marine litter predominantly consists of Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG), such as nets, ropes, traps, and hooks. These items, often referred to as "ghost gear," are a persistent threat due to their long lifespan and harmful impacts. Additionally, fishing vessels generate other forms of waste from vessel operations or abandonment. From artisanal fisheries, an important component of fishing in the Mediterranean Sea, to industrial fleets—the presence and accumulation of such waste is a pressing environmental concern, with impacts that may be environmental, social, economic and even political.

Resolving the issue of fishing-related litter is particularly complex in the Mediterranean due to several interlinked challenges, including fragmented regulation**,** cost barriers, Limited Awareness and Enforcement. Tackling fishing vessel litter in the Mediterranean also requires a comprehensive, collaborative strategy to prevent gear loss, recover and recycle waste, promote innovation and strengthen cooperation.

By answering these questions and pursuing an integrated approach, stakeholders can mitigate the impacts of fishing vessel litter. Protecting the Mediterranean Sea is not just an environmental imperative but also a socio-economic necessity, ensuring the sustainability of marine resources and the resilience of coastal communities for generations to come. Such an approach requires a thorough understanding of the issue of waste generated by fishing vessels. Relevant information on the nature, sources, quantities, distribution, and, of course, the impacts of waste from fishing activities is essential to provide all the key elements needed for better management by fishers, environmental and fisheries managers, and Mediterranean states.

This report offers an updated overview of the knowledge on the issue of waste originating from fishing vessels in the Mediterranean. This document was developed based on reports and official documents from the Regional Activity Centres (SPA/RAC, MEDPOL, REMPEC, Plan Bleu) of UNEP documents from the UNEP/MAP Regional Action Plan on Marine Litter, as well as documents from the GFCM and FAO dedicated to fishing activities in the Mediterranean and their impacts. It also draws on reference documents from United Nations agencies, notably IMO, and the Intergovernmental Oceanographic Commission (GESAMP group), as well as scientific literature published by international experts and scientific institutions from all Mediterranean countries.

2 FISHING, FISHING VESSELS, WASTE, AND LITTER

2.1 Global Fisheries Production and fishing fleet

In 2022, global fish production peaked at 223 million tonnes (472 billion USD in value from production), with 41.5% originating from capture fisheries and 58.5% from aquaculture (FAO, 2024). Approximately 72% of this production was destined for human consumption. Capture fisheries, plateaued since the 1980s at approximately 90 million tonnes, are predominantly marine based (87.2%, FAO, 2018), encompassing artisanal, recreational, commercial, and industrial sectors, and varying widely in scale and operation.

Small-Scale Fisheries (SSF) are diverse and community-based, emphasizing local traditions and values. They play a crucial role in food security and livelihoods, employing an estimated 60 million people directly or through related activities (FAO, 2018). Characteristics of SSF include (i) the use of small vessels (often under 24 meters in length), (ii) limited capital investment and low technology, and (iii) predominantly localized operations, close to shore. In the Mediterranean and Black Sea, SSF represent over 80% of the active fleet and contribute significantly to employment and coastal economies (FAO, 2023). SSF, contributes to over 40% of world catches, involving 90% of the workforce from capture fishing (FAO, 2024a), and include artisanal fisheries, focusing on small-scale, traditional fishing methods catering primarily to local consumption.

In contrast, Large-Scale Fisheries (LSF) deploy large, high-capacity vessels often equipped with advanced freezing and processing facilities. These vessels, exceeding 24 meters in length, operate globally and are responsible for significant fish production. Key characteristics (GESAMP, 2021) include (i) the use of high-tech, expensive equipment, (ii) extended fishing trips ranging from weeks to months, and (iii) the predominance of factory boats, purse seiners, and trawlers. Despite accounting for half of global fish production for human consumption, LSF employs only around 10% of the fisheries workforce (FAO, 2024).

The global fishing fleet in 2022 was estimated at 4.9 million vessels, with Asia accounting for 75% of this total (FAO, 2024). In 2018 (FAO, 2018), the fleet included motorized vessels (61% of the fleet), primarily operating in Asia, large-scale vessels (2% of motorized vessels), predominantly in Europe, North America, and Oceania, and small-scale vessels (86% of the global fleet), often undecked and non-motorized. The global fishing population in 2016 comprised 59.6 million individuals, 67.3% of whom were engaged in capture fisheries.

Recreational fishing involves the capture of aquatic animals for non-commercial purposes, often driven by leisure and economic value (GESAMP, 2021). Globally, an estimated 225 to 700 million recreational fishers are active in marine and freshwater environments. In the United States alone, 9.6 million saltwater anglers undertook over 63 million fishing trips in 2016. Predominant gear types include hook and line, with other specialized equipment used depending on regional practices.

The increase in both industrial and pleasure fishing and boating across the globe has created a growing demand for fishing vessels with advanced features such as durability and customization, attracting vessel buyers (GESAMP, 2025). The demand for fishing vessels is anticipated to further increase in the future.

In 2020, approximately 62% of the global motorized vessels comprised the global fishing fleet (**Figure 1**; FAO, 2022). Approximately 81% of the world's motorized fishing vessels with known length classifications were under 12 meters in length, and the majority were undecked. The vast majority of the world's non-motorized vessels (about 97%) are in Asia and Africa. The European Union fishing fleet register lists 81,167 active fishing vessels, of which 51,861 vessels fall into the length category of under 8 meters, with the majority made of fibre-reinforced polymers.

FAO conducted a review of the techno-economic performance of the 103 major fishing fleet segments and 240,000 fishing vessels worldwide during the period 2016–2019 (Van Anrooy et al., 2021). The analysis reveals an increase in the average gross tonnage of individual vessels in all fleet segments. The age structure of the fishing fleets of (semi-) industrial fishing vessels in North and South America, Africa, and Europe generally demonstrates an aging trend, while most fishing fleet segments in Asia are younger, due to the rejuvenation of fishing fleets in China, Bangladesh, India, and Indonesia.

Based on current developments, FRP (fibre-reinforced polymer) material, which may be an important source of plastic pollution (GESAMP, 2025, in press), is potentially the top alternative to wood for building fishing vessels. However, initiatives to introduce FRP as an alternative construction material still face challenges in some countries, including acceptance by the fishers themselves (Wibawa et al., 2018). Fishers' knowledge and experiences regarding FRP as a construction material, the suitable design of vessels for specific fishing communities, and proper infrastructure to support FRP vessel industries are significant constraints. Nevertheless, the manufacture of small fishing vessels remains particularly important, with about 80% of vessel hulls up to 20 meters in length constructed from FRP (Rubino et al., 2020), noting a trend towards larger vessels, despite a decreasing number of vessels (FAO, 2020).

2.2 Fishing in the Mediterranean Sea

The operating fishing fleet in 2022 in the Mediterranean totalled 73,290 fishing vessels with a total capacity of approximately 750,000 gross tonnage (GT) (FAO, 2023a), showing a small decrease of 1.2 percent in numbers and a small increase of 3 percent in GT. Four countries (Tunisia, Greece, Italy, and Türkiye) account for 58 percent of the total fishing fleet from both the Mediterranean and Black Sea, while 63 percent of the total fishing capacity (in GT) is represented by five countries, including Türkiye (18%), Italy (14%), Tunisia (12%), Egypt (10%), and Algeria (9%). These figures indicate priority areas to consider for assessing the environmental impacts of marine litter from fishing vessels. In the western Mediterranean, Algeria (34.7%), Spain (29%), and Italy (15.1%) account for 78.8% of total landings. In the Adriatic Sea, Italy (50.9%) and Croatia (45%) represent 95.9% of landings. The central Mediterranean is dominated by Tunisia (67.4%), Libya (15.6%), and Italy (11.6%), contributing 94.6%. In the eastern Mediterranean, Greece (34.2%), Türkiye (30.6%), and Egypt (29.2%) make up 94% (**Figure 2**).

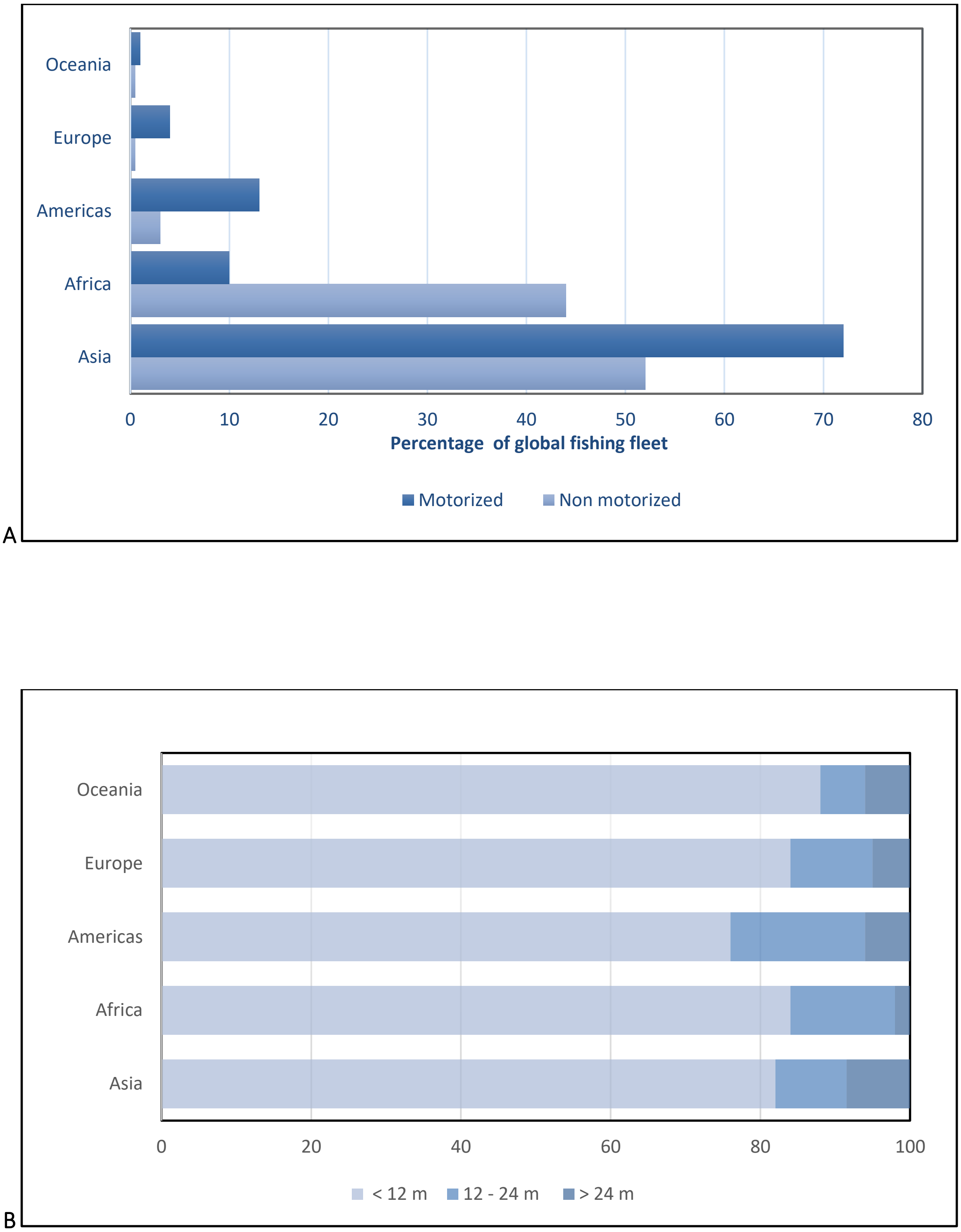


Figure 1. Proportion of global fishing vessels with and without engine (A) and size distribution by continent (B) (After FAO, 2020)

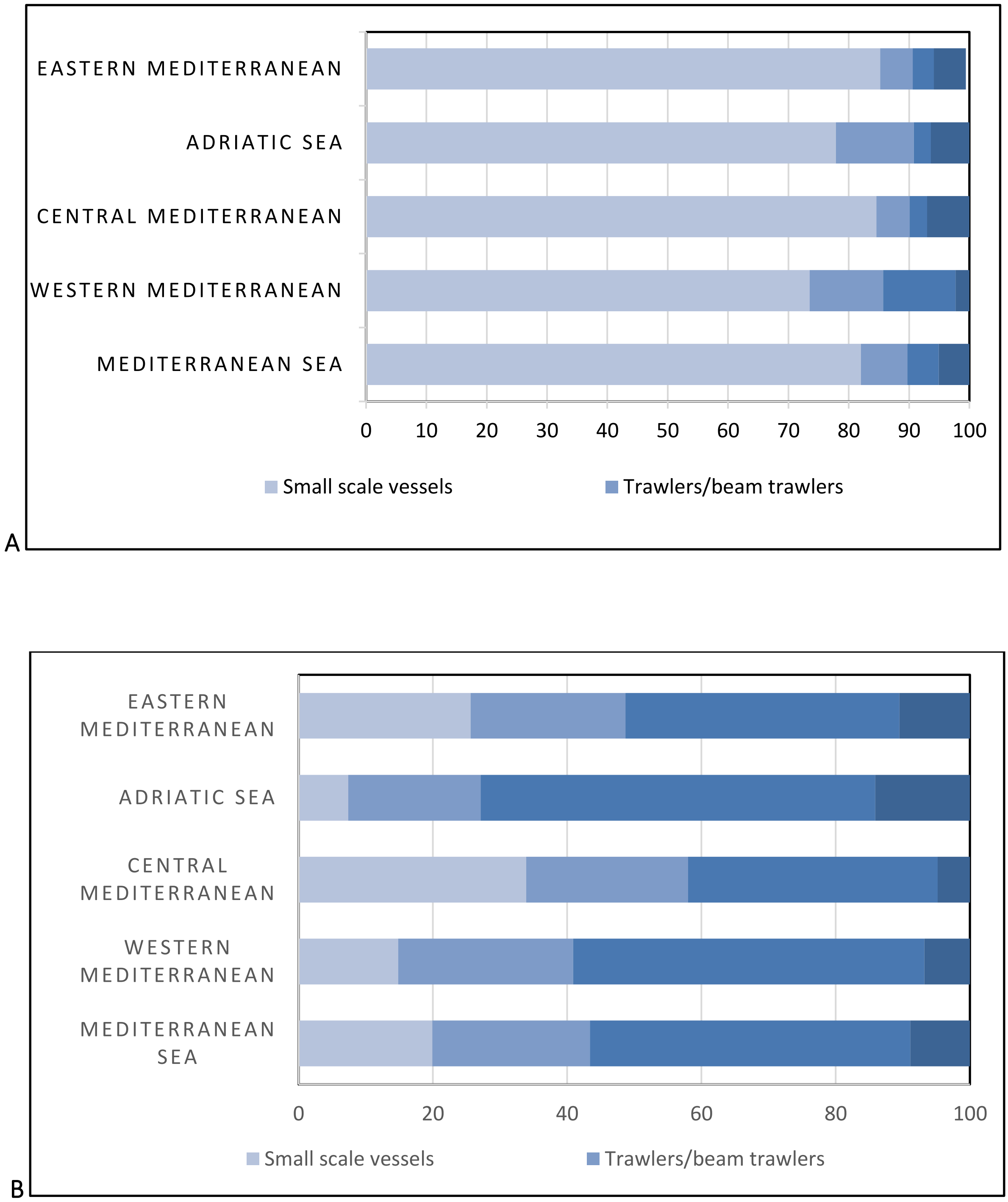


Figure 2. Fleet segment composition (A) and relative contribution of the Fleet segments groups to the total landings (B) in the Mediterranean Sea (Monaco and Bosnia Herzegovina are not included) (Data from GFCM, adapted for the Mediterranean Sea, after FAO, 2023a)

Fishing in the Mediterranean and Black Sea has a long history, with some methods and tools persisting since ancient times, albeit with modernized materials and techniques. Fishing gear in the Mediterranean falls into two broad categories: (i) Active Gear, operated using propulsion systems or winches, including trawls, seines, and dredges, and (ii) Passive Gear, relying on fish behaviour, including gillnets, trammel nets, longlines, and traps. The FAO/GFCM catalogue of fishing gear in the Mediterranean (Luchetti et al., 2023) categorizes gear into five key categories from the GFCM Data Collection Reference Framework (DCRF). Trawlers are the most common active gear for demersal and pelagic species, with variants including bottom trawls for ground fish and midwater trawls for pelagic species. Seiners are encircling nets, such as purse seines, effective for schooling pelagic species like mackerel and tuna. Dredgers are used for benthic species like shellfish, including mechanized and hydraulic options. Polyvalent vessels operate both passive and active gear, such as gillnets, traps, and beach seines. Long liners are passive gear targeting species like tuna and swordfish, including drifting and set longlines. Other methods include Fishing Aggregating Devices (FADs), barriers, fences, and harpoons.

There are clear regional variations in gear usage, implying different types of waste generated by fishing vessels (Luchetti et al., 2023). Bottom trawls are widely used for demersal species in the western Mediterranean Sea, alongside traditional traps and purse seines. Heavy dredge use for clams and artisanal beach seines remains significant in addition to trawling in the northern Adriatic, where approximately 2,900 vessels account for 24.6% of the entire Italian fishing fleet (CREA, 2023). In the eastern Mediterranean, fishing is dominated by longlines and gillnets, with increasing trap use for demersal species.

As a consequence, key environmental issues and management objectives have been identified, including (i) Bycatch of vulnerable and endangered species, with a need to promote selective gear to reduce incidental catches (e.g., Turtle Excluder Devices, TEDs), (ii) Energy efficiency, requiring a transition to low-impact gear and renewable energy to reduce carbon footprints, and (iii) Marine litter, necessitating a focus on the impact of lost or discarded fishing gear and proposing innovative retrieval methods and gear marking.

According to the FAO (2023), landings in the GFCM area (Mediterranean and Black Seas) are dominated by European anchovy (*Engraulis encrasicolus*, 342,000 tonnes) and sardine (*Sardina pilchardus*, 141,400 tonnes). In the Adriatic Sea, anchovy and sardine constitute 20.1% and 47.4% of total landings, respectively. Similarly, they dominate in the western Mediterranean (13% and 17.8%) and eastern Mediterranean (14.2% and 14.4%). In contrast, sardinellas (*Sardinella* spp.) and European sprat (*Sprattus sprattus*) are prominent in the central Mediterranean (8%). Species diversity ranges from 15 species in the Adriatic to 44 in the western Mediterranean. Trends from 1970–2021 show fluctuating landings for pelagic species, notably anchovy, sardine, sprat, and round sardinella (*Sardinella aurita*).

More generally, all priority species in the Mediterranean Sea with sufficient information to evaluate trends show improvements in their status in recent years (FAO, 2023). Demersal species such as deep-water rose shrimp (*Parapenaeus longirostris*), common cuttlefish (*Sepia officinalis*), Rapa whelk (*Rapana venosa*), red mullet (*Mullus barbatus*), and surmullet (*Mullus surmuletus*) exhibit increasing trends. However, landings of European hake (*Merluccius merluccius*) and whiting (*Merlangius merlangus*) have declined recently. Sustainable exploitation levels have now been achieved for European anchovy (*Engraulis encrasicolus*) and common sole (*Solea solea*), with a 2% reduction in fishing pressure on sole since 2020. Black Sea turbot (*Scophthalmus maximus*) and Norway lobster (*Nephrops norvegicus*) are approaching sustainable levels, while European hake continues to show gradual improvement due to reduced fishing mortality and harmonized stock assessments.

Despite these advancements, fishing pressure on blue and red shrimp has stabilized, but deep-water rose shrimp (*Parapenaeus longirostris*) remains overexploited, with fishing pressure nearly double sustainable levels. European anchovy exploitation is decreasing, particularly in the western Mediterranean, while sardine (*Sardina pilchardus*) exploitation remains highly variable, averaging double the maximum sustainable yield. This disparity reflects differing responses to similar fishing pressures.

Between 2018–2019 and 2020–2021, aquaculture production has significantly increased in the southern and eastern basins, with notable rises of 11% in Tunisia, 29% in Morocco, 35% in Türkiye, 36% in Egypt, 42% in Algeria, and an exceptional 59% in Albania. These increases suggest these countries may face growing environmental impacts, including marine litter, in the near future. Conversely, aquaculture production has decreased in EU countries, ranging from a 1.4% drop in Cyprus to a 37% decline in Slovenia, except in Malta, Greece, and Croatia, which recorded increases of 5% to 22%. Significant decreases were also observed in Lebanon (-9%) and Bosnia and Herzegovina (-27%).

In addition to transoceanic routes used by large-scale fishing vessels, the locations of fishing vessel routes highlight areas at risk, particularly in the event of accidents or concentrated activity. While in-depth studies of these locations are lacking, tools for maritime navigation and scientific analysis can offer valuable insights. For example, platforms like GlobalFishingWatch.org and MarineTraffic.com maintain databases with up-to-date positions of various vessel types, including fishing vessels with Automatic Identification System (AIS) positioning (**Figure 3**). These platforms also provide data on light emissions and fishing pressure, particularly from GlobalFishingWatch.org. Integrating position and route data over extended time periods can reveal areas of high vessel concentration, where the risks of accidents, gear losses, or abandonment are greatest.

In Europe, the European Commission's EMODNET maritime database compiles position data for fishing vessels and small pleasure vessels, as well as their routes (**Figure 4**). Although these publicly accessible data do not provide exact locations of Abandoned, lost or otherwise discarded fishing Gear, they clearly identify global, national, regional, and local areas where abandonment, losses, or accidents are most likely to occur.

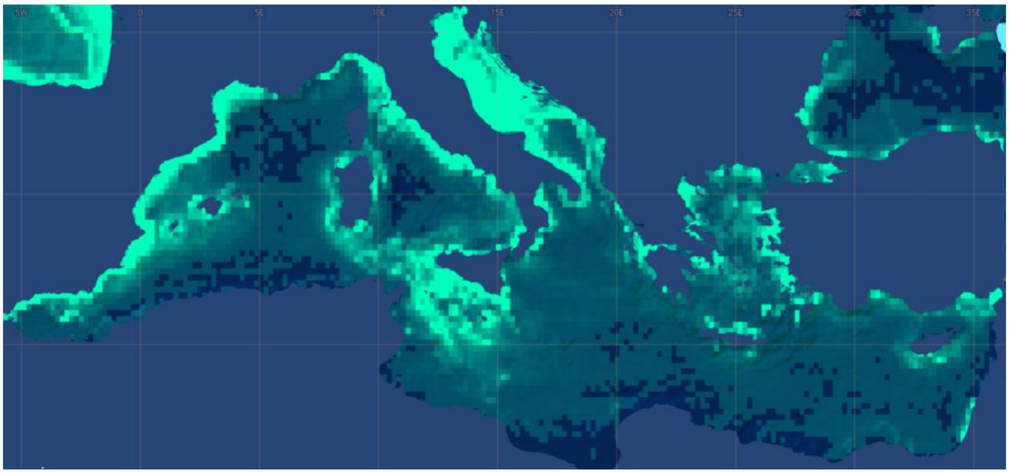


Figure 3. Mediterranean view of fishing activity during the period Jan 2012 to 31 December 2024 and thus potentially at risk for fisheries-based marine litter such as abandoned, lost or otherwise discarded fishing gear (source https://globalfishingwatch.org, Detection by fishing effort includes automatic identification system (AIS) data process by Global Fishing Watch algorithms to determine when and where vessels are fishing.

Figure 4. Average mean fishing intensity in the Mediterranean Sea (Hour per square km per month, measured between 2017 & 2023 (source Emodnet, Emodnet /Map geoviewer)

2.3 Fishing as a source of Marine Litter

Except in remote areas (e.g., remote islands and polar seas) where increasing amounts of litter are more frequently observed, the amount of marine litter found in the world's seas remains relatively constant. Time series data on marine litter in various components of the marine environment (beaches, surface, midwater, seafloor, and biota) indicate that the problem has persisted for decades (Galgani et al., 2021). Although land-based sources dominate in generating marine litter, sea-based sources significantly contribute to the problem. For example, an estimated EU average of 32% of marine litter, with values reaching up to 50% in some sea basins, originates from sea-based activities.

The fishing and recreational sectors are relatively large contributors among sea-based sources, accounting for approximately 30% and 19% of marine litter, respectively, according to Eunomia (2016a) and MAP/REMPEC (2019). It is important to note that the fishing industry includes not only fishing vessels but also vessels not directly used for fishing operations, such as supply ships (notably for aquaculture operations) and catch transport vessels.

From fishing activities, marine litter primarily originates from the operations of fishing vessels, ALDFG, and abandoned or sunken vessels. Additionally, it includes the release of grey water and microplastics from vessel paints.

2.3.1 Fishing vessel operations

Fishing vessels may intentionally or inadvertently release various types of litter into the marine environment, including gloves, storage drums, expanded polystyrene (EPS) fish boxes, and personal waste (GESAMP, 2021). Additionally, individuals engaging in sea-based leisure activities, such as recreational boating and fishing, contribute to marine litter, often through the disposal of single-use items.

Efforts to identify and characterize litter from the fishing industry encompass waste generated by all types of operational vessels. However, these efforts often fail to differentiate between general litter and ALDFG. In the Western and Central Pacific Ocean, an estimated 71% of pollution incidents from purse seine vessels involved waste dumped overboard, while only 13% were attributed to ALDFG (Richardson et al., 2018). For longline fishing, 80% of pollution incidents were related to waste dumping, while 17% were categorized as ALDFG.

Several factors influence litter generation by fishing vessels (Mengo et al., 2023). These include operational aspects such as the number, size, and power of vessels, the duration of time spent at sea, the size of the crew, and the availability of on-board storage for waste. Additional factors include vessel density, the availability and cost of adequate onshore waste disposal facilities, the allocation and charging of waste management costs, awareness of the environmental impacts of marine litter, regulatory requirements for waste disposal, and the level of enforcement. The production of fishing gear waste also varies by day and location. For instance, in Norway, it is estimated that fishing nets and trawl equipment generate 1 kg of plastic waste per tonne of fish farmed or captured, while aquaculture produces 11 kg of plastic waste per tonne of output (MAP/REMPEC, 2019).

Quantifying waste discharged at sea remains challenging due to a lack of direct data. A 2016 impact assessment in Europe estimated that 1.15 million tons of plastic waste may be discharged at sea annually by the fishing sector (Eunomia, 2016a). For the European fisheries sector specifically, estimates of ALDFG range from 220,000 to 266,000 tons (MAP/REMPEC, 2019; Eunomia, 2016a). Data from recent fishing-for-litter programs suggest a gradual decrease in ALDFG, although substantial quantities of "old" ALDFG persist in European seas. These programs aim to encourage the passive retrieval and port delivery of ALDFG, often supported by external funding.

While the introduction of the EU Port Reception Facilities (PRF) Directive has led to an increase in waste being delivered to ports, significant gaps remain. For fishing vessels, the shortfall in waste delivery is estimated to range between 7% and 34% of the total waste that should be processed annually (Eunomia, 2016b; MAP/REMPEC, 2019).

2.3.2 Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG)

Definitions

The term “fishing gear” is defined as “any physical device or part thereof, or combination of items, that may be placed on or in the water or on the seabed with the intended purpose of capturing, controlling (for subsequent capture), or harvesting marine organisms” (MARPOL Annex V, 1973/1978; GESAMP, 2021). This definition highlights the essential role of fishing gear in fisheries and marine environmental management. However, ALDFG represents a significant portion of sea-based marine litter, posing substantial environmental challenges.

To address these issues, the Food and Agriculture Organization (FAO) developed the Voluntary Guidelines on the Marking of Fishing Gear (VGMFG, FAO, 2019c) as a framework to prevent ALDFG and reduce its harmful impacts. These guidelines categorize ALDFG into four distinct types:

- Abandoned Fishing Gear means Fishing Gear over which that operator/owner has control and that could be retrieved by owner/operator, but that is deliberately left at sea due to force majeure or other unforeseen circumstances or force majeure
- Lost Fishing Gear means fishing gear over which the owner/operator has accidentally lost control and cannot be located and/or retrieved by the owner/operator
- Discarded Fishing Gear means fishing gear that is released at sea without any attempt for further control or recovery by the owner/operator
- Derelict Fishing Gear: A term synonymous with ALDFG but without specifying the circumstances under which the gear ended up in the sea.

The term "ghost gear" refers specifically to ALDFG that continues to fish autonomously, resulting in detrimental impacts on fish stocks and potential impacts on endangered species and benthic environments. ALDFG can vary from complete gear systems to fragments of fishing equipment, such as nets, ropes, buoys, and anchors from nets/Fishing Aggregating Devices, all of which contribute significantly to marine pollution.

Causes for abandonment, loss or discard of fishing gear

ALDFG arises from various environmental, operational, conflict-based, and management-related factors. According to GESAMP (2021), the frequency and magnitude of ALDFG events vary widely across fisheries and regions. Gear loss can occur regularly through normal use, such as hook bite-offs in longline fisheries, or episodically due to irregular events like extreme weather or operational conflicts. ALDFG encompasses both entire fishing gear items and partial components, such as net sections or ropes. The context of the fishing operation, including gear type, depth, and location, significantly influences the likelihood of gear loss. For example, bottom trawls, gillnets, and pots are more prone to becoming ALDFG due to their interaction with the seafloor or limited fisher control during deployment and retrieval (Richardson et al., 2019).

Operational and Gear-Specific factors Influencing the potential for ALDFG
Passive Gillnets and entangling nets with unattended deployment and large dimensionsincrease their susceptibility to loss (GESAMP, 2021, Frenkel et al., 2023). High deployment numbers of pots and traps make also these more prone to loss (Bilkovic et al., 2016), and regular operational losses occur due to wildlife interactions and line breakage of ropes and lines (Richardson et al., 2019). Long liners, but also recreational anglers frequently lose lines, lead weights, and other tackle, with losses influenced by fishing intensity, habitat type, and angler skill (GESAMP, 2021), noting that shore side anglers may experience higher gear loss rates due to terrain challenges compared to vessel-based anglers. Finally, discards of FADs or its components is generally considered uncommon (Gilman et al., 2015), as a retrieved FAD or its components are often refurbished.

Environmental Factors contributing to ALDFG: Seafloor Topography, oceanographic conditions, and Wildlife Interactions:
Natural and artificial underwater obstructions, such as rocky terrains and shipwrecks, frequently cause gear to become snagged, making retrieval challenging or impossible (Akiyama et al., 2007). Fishers often leave portions of gear behind when recovery proves unsuccessful or hazardous. While slack tides or better weather conditions may facilitate gear recovery (FAO, 2016), many items remain unrecoverable, contributing to long-term ALDFG accumulation. Strong currents, waves, and winds can displace fishing gear or submerge marker buoys, complicating retrieval efforts (Macfadyen et al., 2009; Bilkovic et al., 2014). Deeper water depths also reduce the likelihood of successful gear recovery (Frenkel et al., 2023). Severe weather events, such as hurricanes and tsunamis, cause widespread loss and regional accumulations of ALDFG (FAO, 2016). In colder regions, sea ice drags gear, cuts buoy lines, and submerges markers, resulting in significant damage and loss (GESAMP, 2021). Wildlife interactions, such as whale entanglements in fixed-gear fisheries, can lead to gear loss and adverse ecological impacts (NOAA, 2014 & 2015). Gear that becomes detached during such interactions often remains in the aquatic environment as ALDFG. Other wildlife-related incidents include sharks breaking longlines or gillnets and sea lions puncturing marker buoys (Gesamp, 2021).

Equipment malfunction, and poor gear condition:
Fishing vessels and gear may occasionally malfunction, resulting in loss. Additionally, gear that is in poor condition is more likely to break under environmental stress due to general wear and tear and other existing damage (Frenkel et al., 2023). Preventive maintenance and regular inspection are essential to reduce the risk of ALDFG associated with aging or damaged gear.

Gear Conflicts and ALDFG in Crowded Fishing Areas:
High fishing activity concentrations lead to gear conflicts, particularly where passive gear such as pots and gillnets intersect with active gear like trawls. These interactions often result in severe fouling or complete gear loss (Macfadyen et al., 2009; FAO, 2016). In densely fished areas, spatial competition may force fishers to deploy gear in suboptimal or high-risk zones, increasing the risk of loss from other causes. Cross-sectoral and intra-sectoral competition for fishing grounds can also lead to intentional gear interference, including sabotage or theft of gear (Macfadyen et al., 2009). Fishers may cut buoy lines or vandalize gear, resulting in significant ALDFG accumulations. In some cases, buoy lines are deliberately coiled and concealed within the gear before redeployment, leaving no markers for retrieval (GESAMP, 2021).

High-traffic areas also see frequent gear losses caused by vessel interactions with surface markers, including collisions with buoys that sever lines or displace gear (Bilkovic et al., 2014). Gear caught in vessel propellers or entangled with anchors also contributes to ALDFG (Macfadyen et al., 2009).

A study conducted in the western Pacific (Richardson et al., 2018) identified the main causes of gear loss as net snagging (78%) and gear conflicts (19%). The study revealed a correlation between the high percentages of active trawl (68%) and gillnet (26%) fishing vessels, and the percentage of ghost nets attributed to these vessels (70% and 17%, respectively). A significant positive association between fishing effort intensity and gear loss was also detected. The analysis highlighted that the over-allocation of fishing licenses and pressures from illegal, unreported, and unregulated (IUU) fishing led to overcrowding, overcapacity, and increased competition. These factors drive risk-prone operational decisions, resulting in fishing net damage, discard, and loss.

Quantities of ALDFG from fishing

Understanding the quantity of ALDFG, including the loss rates for different gear items, is important to understand the size and scope of the problem, its associated impacts, and to identify appropriate prevention and mitigation interventions at scale. Because fishing gear is custom designed to catch specific target species that vary significantly across geographic areas, most research conducted on ALDFG quantities is gear- and region-specific (reviewed in GESAMP, 2021).

Some areas of the world have made considerable progress in quantifying ALDFG locally and for specific gear types. Examples include research on blue crab pot losses in the United States (Bilkovic et al., 2014; GESAMP, 2021); Dungeness crab pot losses in the United States (GESAMP, 2021); gillnet and entangling net losses, and pot and trap losses in Türkiye (Ayaz et al., 2010; Yildiz and Karakulak, 2016); gillnet and entangling net losses in Europe and the United Kingdom (Hareide et al., 2005); a recent study from India on the causes and levels of ALDFG in selected gillnet and trammel net fisheries (Thomas et al., 2020); and a study on the causes of ALDFG in Northern Australia and Indonesia (Richardson et al., 2018).

However, quantitative data on ALDFG amounts and gear loss rates remain limited or absent in Africa, Antarctica, Asia, and South America. Similarly, data are scarce for FADs (both anchored and drifting), as well as for line losses (handlines and pole-lines), and trawl net losses. Only a few recent studies have addressed these issues in the Mediterranean Sea (Sinopoli et al., 2018; Consoli et al., 2020) and further research is needed to support regional management efforts, including those under the GFCM framework.

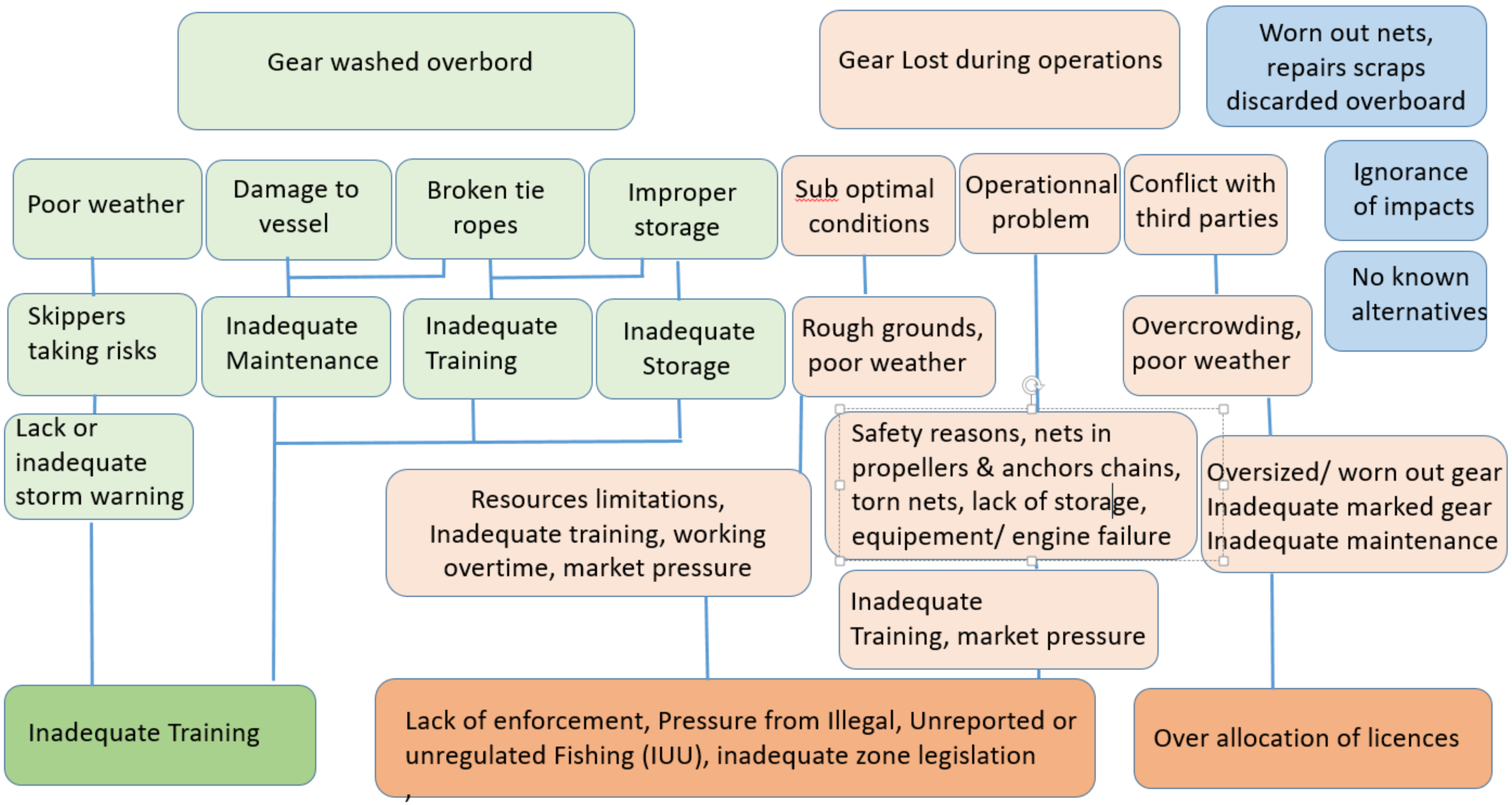


Figure 5. Causes of derelict fishing gear from trawl, gillnet and purse seine vessels. Fault tree symbols and descriptions modified/simplified from Richardson et at al., 2018 (after Acosta and Forrest, 2009). Colours are designed to differentiate between different tree 'branches' to better follow the overall causal flow. Darker colours indicate management causes. Because of regulations, controls, protection, fishing practices, and environmental risks, causes of derelict fishing gear are different between legal and illegal fishing.

The first rigorous effort to statistically quantify a global estimate for ALDFG was completed recently (Richardson et al., 2019). A total of 68 publications from 1975–2017, which included quantitative estimates of fishing gear losses over specified time intervals, were reviewed. These studies required ALDFG estimates to be time-bound to allow for rate estimations. Gear characteristics and operational and environmental contexts influencing gear losses were identified. The literature spanned 32 countries and territories across the Atlantic, Indian, Pacific, and Southern Oceans, as well as the Baltic, Caribbean, and Mediterranean Seas. However, publications were biased toward the United States and Europe and focused primarily on pot and net fisheries, with limited literature for line fisheries.

Recognizing the limitations in the available literature and existing knowledge gaps, the authors estimated that 5.7% of all fishing nets, 8.6% of all traps, and 29% of all lines are lost to the world's oceans annually (Richardson et al., 2019). More specific estimates for a variety of sub-gear types, as well as variations in loss rates across different benthic habitats, were also evaluated (Table 1). In the Gulf of Lion, after a survey that covered 41% of the French Mediterranean gill-netters, the quantity of nets lost per year and per boat was found to range between 0.7 km for red mullet "metier" and 1.2 km for hake and crawfish. The % of lost nets represented 0.2 to 3.2 per boat and per year respectively for hake "metier" and sea bream "metier". For crawfish" metier" this percentage was 1.6% (FANTARED, 2003).

Recognizing the limitations of the data available for review, the study presents opportunities for extrapolation and further analysis. For areas of the world where more extensive research has been conducted, locally focused and fishery-specific studies should be considered most relevant for estimating quantities of ALDFG (e.g. Yildiz and Karakulak, 2016). However, for regions and gear types with significant knowledge gaps, global estimates can be used as a proxy and additional reference for exploring the nature of ALDFG where no other data exist.

Despite the large numbers of people involved in recreational fishing, there is no absolute or estimated quantity of ALDFG produced by this activity. Annual estimates of lead fishing tackle sold by wholesalers, which could provide a rough estimate of lead fishing gear lost in the aquatic environment (marine and inland/freshwater), are between 2,000 and 6,000 metric tonnes per year in Europe and 5,500 metric tonnes per year in the United States and Canada combined (GESAMP, 2021). However, because many anglers purchase new gear as surplus, these numbers do not equate to quantities deposited in the marine environment.

Research conducted in the United States reported that shore side anglers lost 0.18 lead sinkers per hour and 0.23 hooks and lures per hour (Gesamp, 2021). Vessel-based anglers in the Great Lakes region reported loss rates of 0.0127 lures per hour, 0.0081 large lead sinkers per hour, 0.0057 small (split-shot) sinkers per hour, 0.0247 jigs per hour, and 0.0257 hooks per hour (GESAMP, 2021).

A 2009 UNEP/FAO study (Macfadyen et al., 2009) estimated ALDFG at 640,000 tonnes, representing 10% of marine litter from sea-based sources. In 2019, a study conducted in the North Pacific (Lebreton et al., 2022) revealed that the majority of floating material originates from fishing activities. While recent assessments of plastic inputs into the ocean highlight coastal developing economies and rivers as major contributors to oceanic plastic pollution, most floating plastics in the North Pacific can be traced back to five industrialized fishing nations. This underscores the critical role the fishing industry must play in addressing this global issue.

Table 1. Average proportion of nets, pots and traps, file and pound nets, lines lost globally. Data are for major gear types. (After Richardson et al. 2019)

Net Type	Average Proportion of Net Loss	Lower 95% CI	Upper 95% CI
Gillnets and Entangling Nets	0.058	0.050	0.065
Miscellaneous Nets	0.012	0.008	0.016
Purse Seines (net fragments)	0.066	0.059	0.073
Seine Nets (net fragments)	0.023	0.019	0.028
Trawl Nets (net fragments)	0.12	0.11	0.14
All Net Types	0.057	0.050	0.064
All Traps	0.086	0.082	0.089
All Line Types	0.29	0.28	0.31

Using remote observations of fishing vessel activity combined with technical fishing gear models, Kuczenski et al. (2021) provided a bounding estimate for gear operation and loss worldwide in 2018. The authors estimated that industrial trawl, purse seine, and pelagic longline fisheries operated 2.1 million tonnes of plastic gear in 2018, with a median estimate of 48,500 tonnes of plastic gear lost during use. These findings suggest that the flow of derelict gear into the ocean from industrial fisheries is approximately 100,000 tonnes per year, while the flow from small-scale fisheries remains unknown.

Interestingly, benthic litter abundance data were extrapolated from the *Dive Against Debris®* citizen science project database, which comprises 11,082 dive records in shallow marine waters (mean depth of 14.85 m) from 119 countries (Consoli et al., 2024). The results indicated the collection of 1,110,113 benthic litter items by volunteer divers, with a global average litter density in marine waters of 5,323 items/km^2. Fishing gear accounted for 20.89% of the total litter collected globally (**Table 2**).

In a harmonized worldwide litter-types inventory based on data from 112 large-scale surveys across various components of the marine environment, Moralles et al. (2021) found that single-use plastics largely dominate global litter, followed by items resulting from fishing activities (15.5%). Interestingly, synthetic ropes, strings, threads, buoys, and nets represented the majority of items found in open waters (61% of total items), primarily originating from high-income countries—a situation different from that in the Mediterranean Sea.

On the seafloor, whether nearshore or in the deep sea, fishing items ranked fourth among the top items and were mainly parts of fishing gear that had been lost or discarded.

Overall, it can be concluded that any estimate is subject to uncertainties and unknowns. The significant changes that have occurred over the last 50 years in the global scale of commercial fisheries and the materials used in manufacturing gear underscore the urgent need for a more current and accurate estimate of the portion of marine litter that constitutes ALDFG.

Table 2: Mean densities (items/100m2) in number, and percentage (%) of the fishing gear categories calculated for the following macro-regional division (East Asia and Pacific; Europe and Central Asia; Latin America and Caribbean; Middle East and North Africa; North America; South Asia; Sub-Saharan Africa). Data is from the Dive Against Debris® citizen science project database, After Consoli et al. (2024)

MACRO REGION	Nb OF DIVES	TOTAL DEBRIS (Mean)	ARTIFICIAL POLYMERS (Mean)	SUP* (Mean)	FISHING GEAR (Mean)	% FISHING GEAR
East Asia & Pacific	4276	58,32	41,6	21,96	10,68	17,3
Europe & Central Asia	2297	26,47	14,79	6,17	4,51	19,05
Latin America & Caribbean	1573	63,09	39,36	16,73	15,38	26,66
Middle East & North Africa	1269	72,21	51,84	27,55	14,88	13,11
North America	2342	45,33	21,52	7,75	11,51	22,97
South Asia	327	91,62	48,23	12,96	23,17	21,68
Sub-Saharan Africa	289	25,98	17,33	8,66	3,89	17,34

*SINGLE USE PLASTICS

2.3.3 Lost and abandoned FRP fishing vessels

FRP (Fibre-Reinforced Plastic) vessels offer numerous advantages over those constructed from traditional materials such as steel, wood, or concrete. They are lighter in weight, making them easier to handle, transport, and deploy. They are also highly resistant to the corrosive effects of saltwater and possess a high strength-to-weight ratio that enhances their durability. Furthermore, FRP vessels exhibit beneficial thermal and electrical insulation properties. The use of FRP in vessel manufacturing allows for customized designs, enabling manufacturers to incorporate complex structural features that optimize performance and meet specific client demands. Another significant benefit is that damaged FRP vessels are less prone to sinking due to their lower specific gravity and the widespread inclusion of foam cores sandwiched between fiberglass layers.

Since fiberglass became commercially viable for boat production in the 1950s, FRP vessels have typically been designed with a life expectancy of 30–50 years. However, many older vessels, exceeding 50 years of age, continue to remain operational (GESAMP, 2025, in press). This durability has contributed to a growing issue of end-of-life vessels. While these vessels may no longer be financially viable, their substantially intact hulls present limited disposal options (IMO, 2019). The global scale of this problem has become particularly pressing in the context of current negotiations for an international Plastics Treaty, which aims to address plastic waste and contamination in terrestrial and marine environments. Disposal on land is increasingly constrained by a lack of space, and at-sea disposal poses unacceptable risks to marine ecosystems and human health. The gravity of this issue has been raised by parties to the London Convention and London Protocol, with small island developing states (SIDS) being particularly vocal about the challenges they face (IMO, 2016).

The materials used in FRP vessels typically consist of a matrix of polyester, vinyl ester, or epoxy resins embedded with fibres such as glass, carbon, or aramid (GESAMP, 2025, in press). However, the impact of harsh environmental conditions on the long-term durability and structural performance of these vessels is not yet fully understood.

Data on abandoned FRP vessels remain scarce and geographically limited, yet the causes of abandonment are diverse and interconnected. Many vessels are intentionally abandoned due to the lack of recycling facilities or financial constraints. Others are lost through shipwrecks caused by weather, accidents, negligence, structural damage, or navigation errors. Such losses often result in vessels sinking, becoming stranded on shorelines, or persisting for years, negatively impacting harbours and spreading debris that harms marine ecosystems. In some cases, vessels are intentionally dumped, a practice driven by the lack of recycling infrastructure and a reluctance to pay disposal fees (Turner & Rees, 2016). Extreme weather events, such as hurricanes, flooding, and heavy swells, further exacerbate vessel damage or loss. Additionally, boating accidents, often attributed to operator error, inexperience, or recklessness, contribute to the problem.

Estimates from the FAO (2020) and Rubino et al. (2020) suggest there are approximately 2.55 million FRP fishing vessels worldwide, with 25,550–51,000 of these vessels reaching the end of their operational lives each year. The dismantling of these vessels generates an average of 0.77 tonnes of composite waste per boat (APER, 2022). Without effective management measures, GESAMP (2025, in press) estimates that this leads to 19,000–38,000 tonnes of end-of-life fishing vessel waste annually on a global scale. This escalating volume of waste has become a significant concern, with urgent attention needed to address the environmental and logistical challenges it poses. In the Mediterranean Sea, with an estimated fleet of 73300 fishing vessels (FAO, 2023), representing less than 3 % of the fishing flee worldwide, estimates could lead annually from 5,400 to 10,500 tonnes of end-of-life fishing vessels waste.

2.3.4 Marine litter from normal fishing vessels operations

Beyond issues like abandoned fishing gear, lesser-discussed aspects of fishing litter involve plastic contamination from grey water discharge, the use of potentially toxic items (e.g., fish boxes), and plastics worn at sea by fishers.

Fishing vessels generate grey water, a mixture of wastewater from sources such as sinks, showers, and equipment washing. Unlike black water, which contains human waste, grey water is often perceived as less harmful. However, studies indicate that grey water can carry substantial quantities of plastic microfibers and residues that enter the marine environment (Peng et al., 2022). A significant source of these plastics is the detergents and cleaning agents used on-board, which frequently contain microplastics as abrasives or stabilizers. Additionally, clothing worn by fishermen is a key contributor. Grey water discharges from vessels often bypass treatment processes. Moreover, fishing vessels, particularly smaller ones, are typically exempt from the stricter regulations applied to larger commercial ships. As a result, untreated grey water may be directly released into the ocean, exacerbating plastic pollution in regions with dense fishing activity.

In an experiment on a research vessel, Jang et al. (2022) found that the dominant polymer identified in all grey water samples was polyester (53%), followed by polypropylene (23%). Microplastics originating from marine coatings (6%) were also observed in all types of grey water. Annual microplastics emissions per person from grey water discharge on the research vessel were estimated to be 4.1×10^6 n/ person year (equivalent to 3.0 g/ person year), an estimate that may apply to some fishing vessels.

Polystyrene is widely used by fishers for fish boxes to store and transport their catch, buoys, floats, and pontoons, contributing significantly to marine plastic pollution. Despite their lightweight nature, moisture resistance, and thermal insulation properties, these materials present environmental challenges. Polystyrene fish boxes, in particular, degrade under UV exposure, releasing microplastics and potentially toxic substances, such as styrene monomers and oligomers (Kwon, 2023).

Fish stored in degraded polystyrene containers risk contamination, with long-term implications for food safety. To ensure policy coherence, future revisions of food safety regulations (e.g. EC 853/2004 on hygiene rules for food of animal origin, EU 10/2011 on plastic materials in contact with food) should consider the environmental footprint of approved packaging materials, (e.g., risk of lost packaging at sea, toxicity, or recyclability), especially in the fisheries sector where Fish boxes may contribute to the degradation of the marine environment.

Fish boxes and their lids may be accidentally lost from vessels, blown away when inappropriately stored outdoors, or damaged during improper handling, creating fragments that are more likely to be carried by wind or rain into the sea. Like other plastic products and fishing gear, foamed polystyrene can also be intentionally discarded into the marine environment. Buoys and floats, including repurposed materials (e.g. plastic bottles, car parts, etc.) as low-cost substitutes, may similarly be discarded at sea when no longer needed, avoiding the need to transport them back to land for processing. Improper disposal of fish boxes exacerbates these issues. Once in the marine environment, polystyrene fragments into microplastics that persist for years. Studies suggest that polystyrene accounts for up to 20% of floating microplastics in certain Mediterranean areas, especially coastal regions (Collignon et al.; Pedrotti et al., 2022). These particles have been documented in the stomachs of various Mediterranean marine species, including invertebrates and fish, with percentages of total polymers reaching up to 50% (Rios-Fuster et al., 2023).

While polypropylene fish boxes are more durable, their production involves additives like plasticizers, stabilizers, and pigments, some of which leach into the environment over time. Improper handling or disposal of these boxes contributes to marine pollution and introduces hazardous chemicals into ecosystems.

Fishing operations also rely on specialized clothing and gear designed to endure harsh marine conditions. Items such as waterproof jackets, waders, gloves, and boots are often made from synthetic materials like PVC, neoprene, and polyurethane. While essential for ensuring safety and comfort, these materials represent an under recognized source of marine litter. Waterproof gear degrades over time due to exposure to saltwater, sunlight, and repeated use. Small fragments from clothing and gear can detach during routine operations or cleaning. Gloves and boots, subject to heavy wear and tear, shed microplastics when discarded or lost at sea (GESAMP, 2021). In some cases, fishermen discard damaged items overboard due to limited waste management facilities on-board or at port, worsening marine pollution. Unlike organic materials, plastics do not biodegrade; instead, they fragment into microplastics that persist in the environment.

Finally, as for managing used batteries within future renewable energy systems through proper disposal, recycling, and port reception facilities, the repair of fishing gear and equipment at sea is another underappreciated source of plastic pollution. Repairing nets, ropes, and other synthetic gear often involves cutting or trimming materials, leading to the unintentional release of small plastic fragments into the ocean. In high-activity fishing regions of the Mediterranean Sea, this constant, localized source of plastic pollution can accumulate (Rizzo et al., 2024), compounding the broader issue of marine litter. Improved practices, such as collecting repair offcuts and bringing them ashore, are necessary to mitigate this impact.

2.3.5 Microplastics from coatings

Marine coatings, especially antifouling (AF) paints, are essential in the maritime industry to protect vessels and reduce biofouling. However, these coatings have emerged as a significant source of microplastics pollution in marine environments.

The International Maritime Organization (IMO, 2019) reports that approximately 6–7% of marine coatings are lost directly to the sea during a vessel's lifetime. This issue, coupled with the widespread use of microplastics as binding agents in these coatings, presents critical environmental challenges.

The release of microplastics from marine coatings occurs through various processes throughout a vessel's lifecycle. Tamburri et al. (2022) identified seven primary activities responsible for generating microplastics: paint application, ship navigation and operations (microplastics detachment), maintenance and cleaning, in-water cleaning (removal of fouling organisms), routine maintenance (deck and facility coatings), greywater discharge (paints introduced in wastewaters), and ship dismantling.

Marine paints are composed of polymers that act as binding agents, with the solid paint content ranging from 10% to 90%, classified as plastic (Lassen et al., 2015). Paint particles released into the environment are often identifiable by their distinct colours and shapes, reflecting the pigments used in the multiple paint layers (Turner, 2022). According to Magnusson et al. (2016), approximately 6% of solid antifouling coatings are lost to the sea over a vessel's lifetime. Hahn et al. (2018) estimated that between 400 and 1,194 tonnes of marine paint microplastics are introduced annually into European waters, accounting for less than 1% of the total microparticles input in the region. Globally, marine coatings contribute 3.7% of primary microplastics releases into the ocean, amounting to approximately 11,270 tonnes per year or 2.3 grams per capita annually (Galafassi et al., 2019). At the Mediterranean scale, based on a World Merchant Fleet Tonnage registered at 2.3 billion deadweight tons (DWT) in 2024 (UNCTAD data hub) and the gross tonnage of the Mediterranean fishing fleet evaluated at 750,000 tons (FAO, 2023), it is estimated that professional fishing vessels release only about 3.7 tons of microplastics into the Mediterranean Sea annually. While this amount is negligible in terms of physical impact, the toxicity of certain antifouling paints must be considered, especially during paint application, maintenance, or cleaning, rather than during ship navigation and operation (IMO, 2019).

Small-scale ports and marinas emerge as critical hotspots for microplastics emissions due to localized painting and maintenance activities (IMO, 2019; GESAMP, 2025). This is particularly relevant for fishing harbours, where evidence of particles in artisanal fishing harbour sand samples suggests origins from vessel coatings (Torres and De-la-Torre, 2021). The concentration of activities near ports amplifies contamination, affecting coastal ecosystems and marine biodiversity. Additionally, pleasure and fishing vessels, often repainted and cleaned in open environments, exacerbate the issue.

3 ASSESSEMENT OF MARINE LITTER IN THE MEDITERRANEAN

In recent years, marine litter, particularly plastics, has emerged as a significant threat to Mediterranean ecosystems. Pollution levels in the region rank among the highest globally, measured in the volume of litter on beaches, surface microplastics, and seabed waste (UNEP MAP, 2015; Pierdomenico et al., 2023). In the Mediterranean alone, several hundred thousand tonnes of waste are reportedly discharged into the sea annually (UNEP, 2015a), affecting all compartments of the marine environment, including its deepest zones.

Marine litter in the Mediterranean originates from both land-based sources—such as urban waste mismanagement, runoff and storm water discharge, coastal tourism, and rivers—and sea-based activities, including commercial and recreational vessels, illegal dumping, inadequately managed port reception facilities and fishing operations. Studies estimate that plastics, including those from various maritime sources such as packaging, gear components, and consumer items, constitute over 95% of litter on the seabed and more than 85% of floating marine debris. These materials exacerbate existing pressures caused by tourism, urban runoff, and maritime activities.

For macro debris, densities are estimated at around two items per square kilometre (UNEP MAP, 2015a), translating to 62 million floating objects across the surface of the Mediterranean. Additionally, approximately 250 billion microplastic particles float in the basin, making it one of the most affected regions globally (Collignon et al., 2012). Average microplastics concentrations exceed 100,000 particles per square kilometre (UNEP/MAP, 2015a), with peak densities surpassing 60 million particles per square kilometre. Most floating debris originates from coastal sources, except along specific maritime routes such as the Tunisian-Sicilian channel and waters near Malta, where over 60% of debris is attributed to shipping activities.

The aerial survey conducted during the ACCOBAMS initiative (UNEP MAP, 2023) assessed litter across the Mediterranean, recording 41,000 floating mega-litter items. Encounter rates averaged 0.8 items per kilometer, ranging between 0 and 111 items per kilometer. Plastics constituted over two-thirds (68.5%) of observed mega-litter, including plastic bags, bottles, tarpaulins, and inflatable beach toys. Anthropogenic wood waste accounted for 1.9%, while the remainder (27.9%) included other anthropogenic materials.

While general geostrophic current dynamics influence particle movement, the circulation of floating debris in the Mediterranean is particularly complex. Spatial modelling of mega-litter distribution revealed significant variability during summer. Highest densities were observed in along the coast of Catalunya, the Tunisian- Sicilian channel, Northern and central Adriatic Sea, and along the coast of the Levantine basin, notably in Egypt and South East Türkiye (Liubartseva et al., 2015; Jorda & Soto Navarro, 2023). Water circulation patterns are shaped by seabed geomorphology, coastal sources, and turbulent river inputs. Temporary convergence zones, where debris accumulates for a few days to weeks, were also noted (Cozar et al., 2024). Plastic waste is pervasive across the Mediterranean, from coastal areas and enclosed bays to deep-sea zones. Coastal regions with limited water circulation and deep-sea canyons are particularly prone to accumulation (Pierdomenico et al., 2023).

Data from the IMAP Info System (Common Indicator 23 "Trends in the amount of litter washed ashore and/or deposited on coastlines (beach litter)"), covering 367 seafloor trawls/stations across 11 Mediterranean countries between 2017 and 2021, highlighted significant variability in seafloor litter densities (UNEP MAP, 2023). Concentrations ranged from 0 to 28,228 items per square kilometer, with an average concentration of 570 ± 2,588 items per square kilometer, excluding extreme outliers (662,500, 1,882,500, and 372,500 items per square kilometer). The majority of sampling efforts targeted soft-bottom areas through trawling, primarily under the MEDITS project (Spedicato et al., 2019).

Analysis from the MEDITS project identified bottom depth and slope as key factors influencing plastic macro-litter retention. Shallower areas near populated regions exhibited the highest densities, likely due to proximity to human activities and major port cities. While litter densities decreased at intermediate distances from ports, they rose again farther away due to stabilization on gentler slopes and accumulation near seafloor features such as rocks, wrecks, and depressions.

Topography and hydrodynamics further influence litter transport and accumulation, with macro-litter transported by bottom currents and river flows into submarine canyons, where it becomes trapped (Galgani et al., 2022; Pierdomenico et al., 2023).

The model by Spedicato et al. (2019) revealed major accumulation hotspots in the Strait of Gibraltar, Gulf of Valencia, Gulf of Lions, eastern Corsica, central-southern Adriatic Sea, Argosaronic region, eastern Aegean near Asia Minor, Gulf of Salerno, Tyrrhenian Strait of Messina, and southern Cyprus. Hotspots were concentrated in the western and eastern Mediterranean, while the central basin appeared less affected. Other studies (Pasquani et al., 2016) reported high marine litter concentrations in the northern Adriatic, identifying it as one of the most polluted areas.

Using a threshold value (TV) of 38 items per square kilometer, the IMAP assessment (UNEP MAP, 2023) classified 88% of monitored stations as failing to achieve Good Environmental Status (GES). Most stations were categorized as "bad" (53%) or "moderate" (23%), with litter densities up to five times higher than the threshold. The Western Mediterranean was particularly affected, with 100% of stations classified as non-GES. Similarly, 81% of stations in the Central Mediterranean (primarily Tunisia and Sicily) failed to meet GES, while 65% of stations in the Adriatic and 68% in the Eastern Mediterranean were also classified as non-GES. These findings underscore the need for further investigation into the interactions between marine litter and fishing activities. While current assessments focus primarily on environmental status, the operational impacts of marine litter on fisheries remain underexplored. Fishers are not only stakeholders in marine litter mitigation but also directly affected by its presence. Depending on the gear type and fishing area, litter can interfere with operations, damage equipment, and reduce catch efficiency. For instance, bottom trawlers are particularly impacted by seafloor litter, which can clog nets and increase sorting time, while gillnets and other passive gears are more likely to encounter floating debris, such as plastic bags or packaging materials. In some areas, the volume of litter retrieved during fishing operations can be substantial. To better understand and quantify these interactions, further data collection and analysis are needed. Ongoing work by the General Fisheries Commission for the Mediterranean (GFCM), particularly through its related monitoring initiatives, is expected to provide greater clarity on the extent and nature of these impacts across the region. This information will be essential to inform targeted mitigation strategies and support fishers in addressing the challenges posed by marine litter.

3.1 Methods to assess sea floor Litter and ALDFG in the Mediterranean Sea, Importance of sea floor

Monitoring the marine environment for plastic litter and waste from fishing vessels, including ALDFG, is essential for assessing the extent and impact of marine litter, developing mitigation strategies to reduce inputs, and evaluating the effectiveness of these measures. However, achieving meaningful results requires the use of consistent and reliable methods of sampling and sample characterization—such as assessing the number, size, shape, mass, and type of material (GESAMP, 2019). When designing a sampling program, it is important to consider management objectives, environmental settings, and the most appropriate indicators for monitoring (GESAMP, 2019). Indicators typically describe the "state" of the environment, such as the quantity of litter per unit of measurement (e.g., area, length, or number of organisms). Monitoring programs often compare measured conditions against a baseline or reference state for a given area. The magnitude of change to be detected, coupled with the inherent variability in the measured parameter, determines the sampling effort needed to reliably track spatial and temporal trends (GESAMP, 2019).

Numerous monitoring and assessment methods are used in the Mediterranean, developed through scientific projects and regional initiatives. These methods include detailed litter categories specifically addressing waste from fishing vessels and ALDFG (GESAMP, 2019; Galgani et al., 2023; FAO, 2024). Monitoring results have shown that surface and beach litter are less affected by fishing-related items compared to litter on the seafloor (see Section 3.2).

Monitoring seafloor litter, including ALDFG, poses unique challenges compared to beach and floating litter, primarily due to increasing water depths and the remoteness of study areas (Canals et al., 2020). Shallow-water monitoring often relies on SCUBA divers or snorkelers to observe and record litter. These surveys allow for direct observation and detailed analysis of small areas, particularly hydrodynamic traps like rocky outcrops and coral reefs. They also allow for the assessment of litter-biota interactions and the collection of physical samples for inspection (Galgani et al., 2023). Despite these strengths, shallow-water surveys are constrained by depth (20–40 meters) and safety factors such as water turbidity and temperature. Trawl surveys, initially developed for fish stock assessments, have been adapted for large-scale litter monitoring. These standardized methods enable the identification of litter sources and accumulation zones, trend analyses from 20+ years of data collection, and cost-effective integration with ongoing trawl programs. However, some challenges include underestimation due to net mesh size, litter displacement by bottom currents, and the risk of unexploded munitions. Additionally, variability in gear types and methodologies complicates cross-study comparisons (Canals et al., 2020). Advancements in underwater imaging have enabled precise observation of seafloor litter using platforms like Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), and Human-Occupied Vehicles (HOVs). These methods offer accessibility to all depths and complex terrains, including areas inaccessible to trawls, precise geo-referencing of litter, detailed observation of litter-biota interactions, and minimal environmental disturbance, making them ideal for sensitive habitats. However, imaging surveys may underestimate litter due to coverage limitations, sediment burial, and obstructions like seagrasses or reefs.

The regional fisheries monitoring frameworks are also contributing to marine litter data collection. In particular, the GFCM has developed standardized monitoring protocols for discards (FAO. 2019a). and incidental catch of vulnerable species (FAO. 2019b)., which includes a chapter to collect and report a minimum common information on marine litter encountered during fishing operations. While reporting on marine litter is not mandatory, GFCM Contracting Parties and Cooperating non-Contracting Parties (CPCs) are encouraged to collect and submit this data, and many have already begun doing so. Furthermore, a prototype trawler designed to collect marine litter from the seabed has been developed By GFCM and is currently undergoing trials in some areas in the Mediterranean. This initiative reflects growing interest in integrating litter recovery into fishing operations.

Emerging technologies such as stereo cameras, laser systems, and hyperspectral imaging improve litter detection and material classification (Matthias et al., 2023). Moreover, image-based monitoring generates vast amounts of data requiring advanced processing and analysis. Recent innovations include machine learning for automated litter detection and annotation, as well as harmonized reporting units and metadata standards for trend analyses. Efforts are underway to integrate diverse datasets into unified systems, enabling large-scale assessments and long-term monitoring under frameworks like IMAP (UNEP MAP), MSFD for EU countries, and regional projects (e.g., Marine Litter MED).

In the systematic review of the state-of-the-art of 14 current underwater technologies eligible for future in situ detection of litter on the seafloor (Matthias et al., 2023), a set of objectives and a Technology Readiness Level (TRL) scale were used to benchmark the technologies. The review revealed that the most suitable system is often highly scenario specific.

Most of these technologies are currently at low to middle TRLs, requiring further development, testing, and commercialization before they can be effectively applied in marine field conditions. Acoustic systems like Side-Scan Sonar (SSS) and Synthetic Aperture Sonar (SAS) are widely used for large-scale monitoring. These systems offer high spatial coverage, with SAS demonstrating exceptional resolution and the ability to detect objects as small as 2 cm. However, acoustic systems lack the capability to differentiate between plastic and other materials. Additionally, AI integration enhances shape-based classification but struggles with fragmented plastics or bio-fouled items. Thus, training datasets are critical for improving accuracy. Spectral imaging, including hyperspectral and Raman imaging technologies, also provides unparalleled precision by identifying plastics at the polymer level. While these systems are still in experimental stages, they have demonstrated the ability to detect microplastics under controlled conditions. However, their integration with other methods, such as acoustic systems, is necessary for large-scale applications due to cost considerations.

3.2 ALDFG in the Mediterranean Sea

The pervasive issue of marine litter, particularly from fishing activities, has become a significant environmental concern in the Mediterranean Sea. Fisheries- and aquaculture-related categories of litter on beaches may be significant contributors to marine litter in some regions, including the Adriatic and Ionian macroregion (1.54%–14.84%; Vlachogianni et al., 2018). In Spain, almost a third (28%) of stranded or floating marine debris recorded around the Cabrera Marine Protected Area originates from aquaculture and fishing activities (Rios-Fuster et al., 2023). This is attributed to several fishing grounds around the island and input from surrounding countries. However, this trend is not consistently reflected in most studies.

In Algeria, fishing-related litter accounts for 0.9% of litter measured on 17 beaches (Vlachogianni and Skoullos, 2022), while in Morocco, it is 3.2% on 12 beaches (Nachite et al., 2019), 0.6% at five sites in Albania, 4.4% on 58 beaches around the Italian coast (Fortibuoni et al., 2021), and 0.9% in Cyprus (Orthodoxou et al., 2022). In Montenegro, fishing-related items—including nets, ropes, cords, buoys, and similar gear—constitute 20% of the total recorded marine litter items on the coast (29% for floating litter, UNEP MAP, 2019); while they reach 25% in Albania (INCA & UNEP/MAP PAP/RAC, 2019). Surveys conducted on 37 beaches in Morocco, Tunisia, and Egypt (Haseler et al., 2025) revealed an average high density of 3,312 items/100m, with fishing gear, mainly cords, representing less than 3.5% in all three countries. A participatory science experiment in four Mediterranean countries (France, Croatia, Slovenia, and Cyprus) found that fishing litter items did not rank among the top 10 litter categories (Vlachogianni, 2024). Similarly, a survey of 448 beaches in Greece yielded the same pattern (Charitou et al., 2024). On Tunisian beaches, fishing-related items ranked 12th (nets, pieces of nets) and 13th (ropes) among the most common items found (Baccar Chaabane et al., 2024). For floating litter, the ACCOBAMS survey initiative (UNEP MAP, 2023) recorded 41,000 megadebris items at the surface of the Mediterranean Sea, with only 1.7% identified as fishery debris.

On the seafloor, ALDFG is one of the most damaging forms of litter, contributing to plastic pollution, ghost fishing, and habitat destruction. Fishing-related litter includes tools such as nets, lines, traps, and other gear made predominantly from durable plastic materials that persist in the marine environment, causing long-term harm. Traditional Mediterranean fishing activities are locally responsible for significant contributions to marine litter. Documented examples include litter from fish aggregating devices in the Tunisian-Sicilian channel (Sinopoli et al., 2020; Consoli et al., 2020), plastic pots (used as alternatives to traditional clay pots in some areas) and traps used to catch octopuses in Tunisia (Chouchenne et al., 2021), and mussel socks in the northwest Adriatic (Pasquini et al., 2016; Mistri et al., 2024).

However, important gaps remain, particularly regarding small-scale fisheries, with insufficient data to assess the origins, impacts, and management measures. As a result, data scarcity and inconsistent methodologies hinder comprehensive assessments. Projects like FANTARED (2003) in the north-eastern Mediterranean, DefishGear in the Adriatic, and LIFE-GHOST in the northern Adriatic have provided localized insights, but region-wide data remain fragmented.

In a comprehensive regional survey across 11 Mediterranean countries to assess the occurrence, impacts, and management of ALDFG and ghost nets, data on marine litter and ALDFG trends were collected in 2015 (UNEP MAP, 2015b). The study also evaluated existing management practices and regulations, aimed to understand stakeholder perceptions (especially fishers), and promoted initiatives like "Fishing for Litter" as solutions to mitigate the problem. A total of 557 respondents participated, with aggregated results showing that most fishing activity occurs within national waters, using longlines, hooks, and trawls as predominant gear types. Annually, thousands of meters of fishing gear are lost, with gillnets and longlines being most vulnerable to loss or abandonment. Fishers reported frequent encounters with marine litter in their nets, and nearly half identified specific litter accumulation hotspots. On-board waste management was found to be inadequate, with 38% of respondents admitting to discarding waste at sea. At ports, waste reception facilities were either absent or insufficient, with accessibility cited as a major barrier. Ghost fishing was identified as a growing problem in regions with intense fishing activity, with 64% of respondents observing a worsening trend.

Further analysis of data on seafloor macro-litter within IMAP (UNEP MAP, 2023) focused explicitly on fisheries-related items to identify hotspot areas in the Mediterranean where high abundance rates impact biota (e.g., through ghost fishing and ALDFG). Fisheries-related items account for up to 10% of the total recorded seafloor marine litter in the Mediterranean (UNEP MAP, 2023). Commonly recorded fisheries-related items include synthetic ropes/strapping bands (39%), fishing nets (polymers, 27%), and fishing lines (polymers, 25%). Other items recorded in smaller percentages include natural fishing ropes (6%), other synthetic fishing-related items (2%), and hooks or spears (1%). The prevalence of fishery-related marine litter varied significantly by country. On average, France recorded approximately 26 items per square kilometer, while Israel reported the lowest density with about one item per square kilometer. Intermediate values were observed in Türkiye (approximately 19 items/km²), Malta (15 items/km²), Tunisia (8 items/km²), and Croatia (3 items/km²).

At the Mediterranean scale, data from the science project Dive Against Debris®, based on 1,581 dives conducted in shallow coastal waters (mean depth 15 m) in Mediterranean countries, showed that 12.4% of litter originated from fisheries-related activities (**Table 3**).

More detailed studies have provided relevant information in certain fishing areas of the Mediterranean Sea. From September 2009 through May 2010, face-to-face interviews were conducted at 27 fishing ports in Türkiye, resulting in a total of 282 questionnaires (Yıldız and Karakulak, 2016). Estimates of lost fishing gear included 229.48 km of set nets, 2,700 m of longlines, and 14 fish traps. Turbot nets had the highest loss ratio (54.73%), followed by bonito nets (16%), red mullet nets (7.36%), and encircling trammel nets (4.83%). The four major causes of net loss were conflicts with other gear types (trawl and purse seine), conflicts with cargo vessels, bottom structure hindrances, and bad weather conditions. Bottom structures were the sole factor in the loss of longlines and fish traps. The study observed that large quantities of nets had been lost, with each net type showing a positive relationship between the number of nets used and the number of nets lost.

Table 3. Mean densities (items/100m2) in number, and percentage (%) of the fishing gear category calculated for 16 Mediterranean countries participating in the project Dive Against Debris. Data is from Dive Against Debris ® citizen science project database, After Consoli et al. (2024)

COUNTRY	Nb of DIVES	TOTAL (mean)	ARTIFICIAL POLYMERS (mean)	FISHING GEAR (mean)	% FISHING GEAR
Croatia	8	17,65	9,72	1,48	6,21
Cyprus	86	33,73	21,19	1,74	3,95
Egypt, Arab rep.	299	105,46	70,91	12,51	8,67
France	46	66,19	54,54	1,42	1,93
Gibraltar	2	173,97	96,05	10,11	4,73
Greece	349	37,07	15,61	2,80	7,72
Israel	1	33,64	23,91	6,81	27,55
Italy	97	57,14	36,68	3,16	6,64
Lebanon	1	0,21	0,21	0,00	0
Malta	284	26,16	15,62	1,67	6,65
Montenegro	1	2,07	1,00	0,08	3,68
Slovenia	3	72,57	25,64	6,17	7,22
Spain	296	25,34	16,22	4,50	15,62
Tunisia	73	16,80	7,66	12,52	70,21
Türkiye	19	9,53	5,72	3,30	8,45
TOTAL	1581	46.5	28.6	14,3	12,4

A monitoring program for coralligenous assemblages was carried out in Italy as part of the implementation of the Marine Strategy Framework Directive (MSFD). The program aimed to characterize the environmental status of coralligenous habitats and litter distribution, providing a baseline to assess the efficiency of mitigation measures (Angiolillo et al., 2023). A standardized monitoring protocol based on ROV imaging was applied, and the data from the first MSFD cycle (2015–2019) were analysed. Ninety-five areas were monitored at depths ranging between 14 and 199 m across the three sub regions bordering Italy. The median litter density was 2 items per 100 m² (range: 0–120 items per 100 m²), with significant sub regional differences in litter quantities and composition. Fishery-related litter (mainly lines, ropes, and nets) was the most common type (86%), affecting vulnerable coralligenous reefs particularly in Liguria, Campania, Lazio, and Sicily, as well as to a lesser extent in Puglia and Tuscany.

In a study conducted in Morocco, Mediterranean Part, fishery-related litter accounted for just 4% of all items found during SCUBA diving surveys (Nachite et al., 2019). Among these, the most common item was fishing lines (polymers), comprising 34% of the total, followed by fishing nets (polymers, 19%), other synthetic fishing-related items (12%), hooks and spears (12%), natural fishing ropes (12%), and synthetic ropes/strapping bands (9%).

In another study conducted in the Gökova Special Environmental Protection Area (SEPA) in the eastern Mediterranean Sea, 56 owners of fishing vessels (67% of the local fishing community) were interviewed, supplemented by diving surveys at 14 locations to locate and identify lost fishing gear and estimate the extent of the loss. Results showed that 0.84% of gillnets, 3.41% of trammel nets, and 79.2% of longlines were lost during 2007, with the major cause of gear loss being snagging on bottom structures. Diving surveys scanned 22,600 m² of the seabed, estimating 157 m of gill and trammel nets and 36,280 m of longlines per hectare. Lost trammel and gill nets were found to be ghost fishing, indicating the need for their removal from the ecosystem.

An analysis of scientific literature evaluated the presence of fishing-related items on the seafloor in 15 Mediterranean countries (**Table 4**). Data were obtained through trawling or video recordings using ROVs, showing highly variable amounts of marine litter related to fishing. The presence of waste from fishing activities was particularly significant in and around fishing grounds, with a typology characteristic of the activities in the region.

The highest observed densities were recorded in the Tunisian-Sicilian Channel, with waste densities reaching 21,300 items/km² and 46,300 items/km², over 95% of which originated from fishing activities (Consoli et al., 2018 & 2020). In the southern part of this area, fish aggregating devices dominated (83%), while lines and ropes were more prevalent in the northern area (85%), reflecting differences in fishing techniques and the link between fishing activities and the type and quantity of fishing-related waste on the seabed. Similarly, in the northern Adriatic, fishing-related waste accounted for up to 48% of the total waste (Mistri et al., 2024). Significant amounts of trawl nets (29% of the waste), cables, lines, and mussel and oyster socks (up to 30%) justified the need for necessary measures.

During a Fishing for Litter operation (Pasanisi et al., 2023), three hotspots were identified near the Venice Lagoon, in the centre of the northern basin, and at greater depths in the central Adriatic. These areas exhibited significant densities of mussel socks (north), strings and cords, ropes, and nets. In the southern Tyrrhenian Sea, fishing-related waste accounted for 71% in the Aeolian Islands (Consoli et al., 2021) and 77% in southwest Sardinia (Cau et al., 2017), characterized by artisanal coastal fishing equipment, including nets and lines.

Other regions appear less affected, with fishing-related items making up 15–20% of the waste. However, the typology of waste highlights the significance of locally used equipment, such as octopus pots and trawl nets in Spain and Morocco (García-Rivera et al., 2017, Mghili et al., 2023) or fishing lines in Greece (Kouvara et al., 2024). In some areas, fishing-related items accumulate in addition to non-fishing-related waste, transported from surrounding regions, such as in the Balearic Islands (Alomar et al., 2020) or the Levantine Basin (Gönüdal et al., 2024). These accumulations sometimes reach deep zones like seamounts (Angiolillo et al., 2021), where single-use plastics are less prevalent.

An analysis of data from surveys conducted by European laboratories between 1999 and 2011 (Pham et al., 2014) showed that in canyons, plastics were the dominant litter items (50%), followed by fishing gear (25%). On slopes, fishing gear was the dominant litter item (59%), followed by plastics (31%). Furthermore, some studies highlight areas without fishing-related waste or where its presence is masked by high accumulations of non-fishing-related waste (İnal et al., 2025).

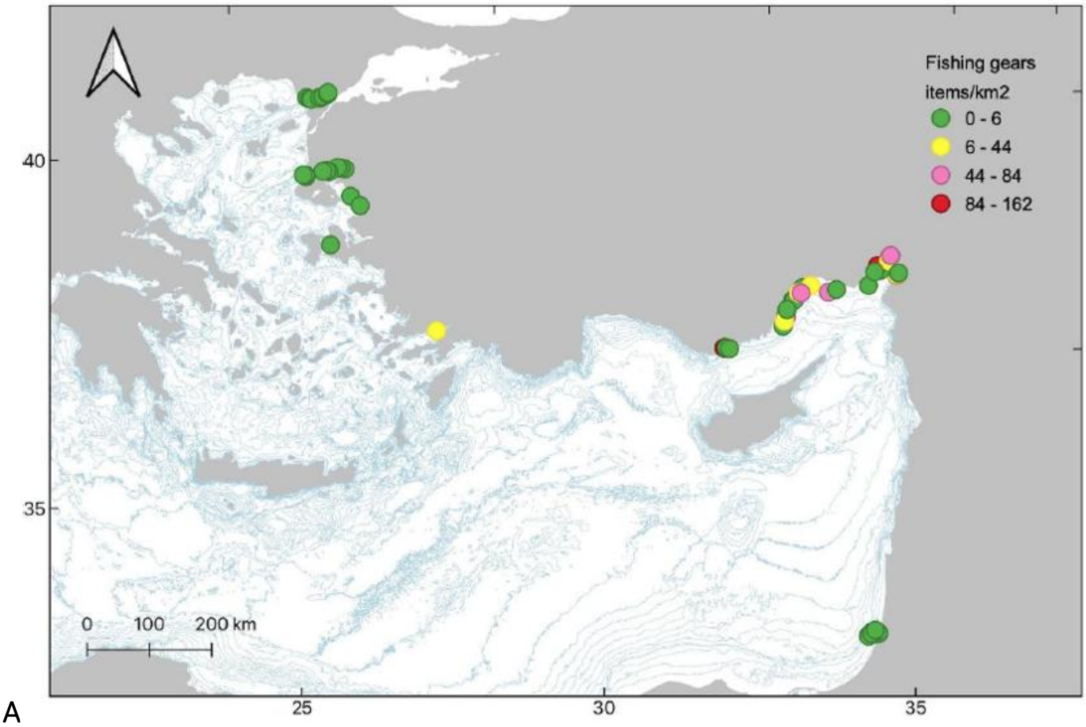
Table 4. An overview of the nature and importance of fishing-related items on the seafloor from various areas of the Mediterranean. Data were collected from scientific literature published over the last 10 years.

REGION	COUNTRY	ZONE[1]	METHOD	NUMBER OF SITES	DEPTH	MARINE LITYTER DENSITIES	% FISHING RELATED ITEMS	MAIN TYPES OF FISHING GEAR	REMARKS	REFERENCES
All Mediterranean basins	11 countries	ALL	Diving	172 sites (468 Dives (2011-2018)	<30m	4355 items/km2, 31.93 Kg/km2	14,8	Fishing lines (4.96%), fishing sinkers, lures and hooks (3.82%)	Project Dives Against Debris	Consoli et al., 2020
Eastern basin	Türkiye	Iskenderun Bay	Trawling	34 hauls	70m (mean)	450.94 item/km2 (90.34 kg/km2)	5%	NC		Büyükdeveci and Gündogdu (2021)
EASTERN Basin	Türkiye	Mersin bay	Trawling	132 hauls	20-180	72 (1–585 kg)/h	7	No details		Eryaşar et al. (2014)
Eastern basin	Israel	Coastal areas	Trawling	156 hauls	20-1600	4700 items/ km2	< 10%	Ropes, nets, fishing lines, and boat rust		Segal & Lubinevsky (2023)
Eastern Basin	Greece	Gulfs of Saronikos, Patras, Echinades	Trawling	69	10-450	75	12,20%	Fishing lines		Ioakeimidis et al. (2014)
	Cyprus	Limassol Gulf	Trawling	9	90-420	24 ± 28	0%	None	No litter from fishing	
Eastern basin/	Greece	Saronikos Gulf	Trawling	70 hauls (2014)	50-350	12,145 items/km2	20%	Fishing line (10%), ropes (5,8%), nets (4,4%)	Increase of fishing related litter with depth	Kouvara et al. (2024)
Eastern basin	Greece	Saronikos Gulf	ROV/video	2 sites (7,8 km2)	96–115	4460 items/km2- (22.7 items/km)	13%	Monofilament, fishing lines, synthetic ropes, fishing nets		Ioakeimidis et al., (2015)
Eastern basin	Greece	Cyclage/ syros harbor bay	Towed camera	6 surveys (2016-2019), 83 km2 (full harbor bay)	1-43	>20000 items/km2	<5%	Ropes,	metallic objects estimated at (15% of litter	Fakiris et al. (2022)
Adriatic Sea	Italy	Northern Adriatic	Trawling	251	10-50	13.4 ±19 kg km2	47.7 %	Mussels socks (29%), traw nets (27%), cables	Fishing for litter scheme	Mistri et al. (2024)
Adriatic Sea	Italy	West Central and North West Adriatic	Trawling	67 stations	10-260	913 ± 80 items/km2	29%	Mussel socks (20%), nets, ropes, lines	Importance of aquaculture as a source	Pasquini et al. (2016)
Adriatic Sea	6 countries	West Adriatic + NE Italy	Trawling	121 hauls	10-120	10 to 2145 items/ km2	#10%	Mussel socks (6% of total ML, ropes	SE and NW Adriatic the most affected	Fortibuoni et al. (2019)
Adriatic Sea	Italy	North Western Adriatic	ROV/ Video	17 dives (19,5km)	20-25	33000 items/km2	88% from fishing & aquaculture	Ropes (62%), nets (18%), mussels sock	Importance of aquaculture, limited number of gillnets	Melli et al. (2017)
Adriatic Sea	Italy	North Western & central western Adriatic	Trawling	37 sites, 245 hauls	20-100	32.6 items: Km2 (5.6kg / km2)	18.7	Mussel socks (north), strings and ropes, nets	Fishing for litter, 3 hot spots	Pasanisi et al. (2023)

[1] Information on whether the location falls within a fishing area, protected zone, or other specific designation, is not systematically available and may only partially reflect such coverage.

Adriatic/North Ionian	Italy, Slovenia, Montenegro, NE Greece	Continental shelves	Trawling	11 (121 hauls)	10 - 281	10-45	5%	Ropes	Importance of aquaculture	Fortibuoni et al. (2019)
Central Mediterranean Sea	Malta	Malta	Trawling	44 hauls	49–697	97 items/km2	13			Misfud et al. (2013)
Central basin	Malta, Italy, Tunisia	Tunisian-Sicilian channel	Trawling	600 sites	100-800	83 items/ km2	12	Presence of FAD	Presence of hotspot; higher density in deepest areas	Garofalo et al. (2020)
Central basin	Italy	Tunisian-Sicilian channel	ROV/ Video	7 sites, 19 transects	20-220	21300 items/km2	98	Lines (85%) and ropes	Fishing grounds	Consoli et al. (2018)
Central basin	South Malta	Tunisian-Sicilian channel	ROV/ Video	2000m	250-400	46300 items/ km2	96	83 % FAD		Consoli et al. (2020)
North Ionian	Italy	North Ionian Sea/ Messina Strait	ROV/ Video	7 dives	243–581	1200/km (max at 20000)	0,9	No details		Pierdomenico et al. (2019)
Western Basin	Algeria	Whole coast	Trawling	65 sites, 254 fishing hauls (2016-2022)	22-660	1350 and 5813 item/km2	3.8 %	NC	Hotspot in Bejaia	Inal et al. (2025)
Western Basin	Morocco	Mediterranean coast	Trawling	50 hauls	25-200	297-957 items/km	28.3%	Octopus pots (>6%), Nest, ropes	Densities decrease with increasing depth	Mghili et al. (2023
Western basin	France	Gulf of Lion, Corsica	Trawling	88 sites (1440 hauls, 1994-2017)	10-800m	49.63 - 289.01 items/km2	6	Fishing nets	Inter-annual variability	Gerigny et al. (2019)
Western basin	France	Bay of Bejaia	Trawling	5 sites, 180 hauls (2010-2019)	40-100m	590 kg/ha	Uncommon		Highly urbanized area, hot spot of marine litter	Mankou-Haddadi et al. (2021)
Western Basin	Italy	Gulf of Policastro	Pole trawling	25 hauls	100-600	651.12 ± 130.61 items/km2	1,5% (shallow waters; 8,5% deep waters	Fishing lines, pieces of net	From fishing for litter operations	Rizzo et al (2024)
Western Basin	Spain	balearic islands	Trawling	806 hauls (2001-2015)	38-800	1.39 kg/km2	13,49	NC	Exposed to trans-border transportation	Alomar et al., 2020
Western Basin	Spain	Gulf of Alicante	Trawling	886 hauls (233 km2)	50-700	22 kg/ km2	15%	Pots, ropes, trawl nets		Garcia-Rivera et al. (2017)
Western Basin	Italy	Aeolian islands	ROV / Video	ROV (60h video)	15- 411	5700	71.9%	Fishing lines and ropes		Consoli et al., 2021
North Western basin	Italy, Monaco, France	Ligurian sea, Cote d'Azur	ROV/ Video	ROV/ 7 dives	340–2200	563 items/km2 (14/km)	52	Fishing lines, no ghost fishing	Fishing gear is found offshore/ deep	Angiolillo et al. (2021)
Western Basin	Spain	Catalunya/canyons	ROV / Video	ROV/ 26 dives	140 - 1731	15057 and 8090 items km2	16,9	Long lines, nets	Fishing grounds, no ghost fishing	Tubau et al. (2015)
NW basin	Italy	Sardinia	ROV / Video	17	100-480	1750 items/km2	77,80%	From SSF, nets (42%) and lines (20%)	Upper part of canyons, including canyons	Cau et al. (2017)
Western Basin	Italy	Liguria	ROV video	80 ROV dives	30-216	152400–items/ km2	82%	Fishing lines, nets and ropes for 67, 17 and 11% of ALDFG	Number of berths & fishing vessels are good predictors of the abundance seafloor ML	Enrichetti et al. (2016)

Finally, data analysed by UNEP/MAP (UNEP MAP, 2023) confirmed the distribution patterns of fishing gear, as demonstrated for marine litter, indicating accumulation areas in the deepest part of the Gulf of Lion (Figure 6 B). The data also provided evidence of accumulation in the south-eastern part of Türkiye (Figure 6 A), corroborating outputs from modelling studies (Liubartseva et al., 2015; Jorda & Soto Navarro, 2023).



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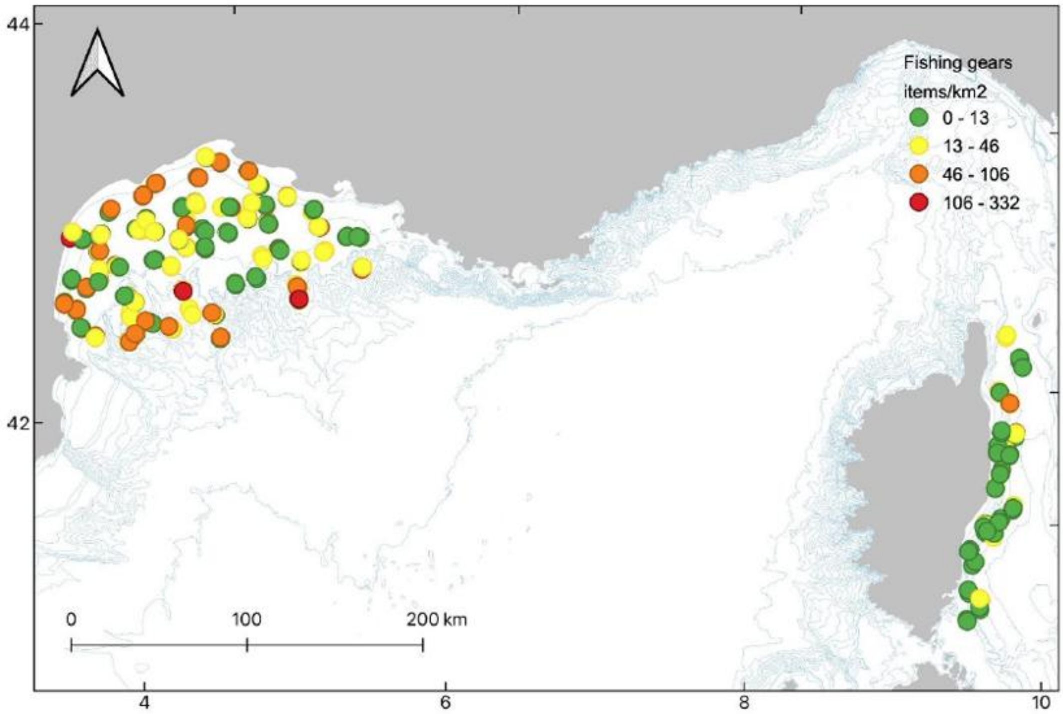

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Figure 6. Fishing gear distribution on the sea floor of the North western (B, France), and The North eastern (A, Türkiye) parts of the Mediterranean Sea (After UNEP MAP, 2023).

CASE STUDY 1:
Fishing Aggregating Devices (FADs) in the Mediterranean Sea

A Fish Aggregating (or Aggregation Device (FAD)) is a man-made object used to attract large pelagic fish. They usually consist of buoys or floats tethered to the ocean floor. Various types of FADs have been employed in the traditional fishing cultures.

In the Mediterranean Sea, this activity is widespread in southern Italy, Tunisia, Malta and Majorca (Spain) (Sinopoli et al., 2020). Throughout the Mediterranean, the design of FADs is very similar and consists of the use of different materials for the floats and for the cables and blocks for anchoring. The different identified materials used to build the FADs are (i) plastic bottles, cork slabs, inner tubes of tyres, and polystyrene slabs (wrapped in plastic sheets), which may remain afloat after being abandoned, (ii) plastic sheets, anchoring ballast (limestone and concrete blocks) and cables/ropes which may sink to the seabed when lost, and (iii) palm fronds, whose fate once abandoned is unknown. FADs are more often placed in coastal areas and shallow waters, randomly at a distance of about 500m from each other, and arranged in lines that reach distances that exceed 20 NM from the coast at greater depths. About 30% of FADs used all over the world are used in the Mediterranean and are only of the anchored type, corresponding to about 90% of those anchored used worldwide. Moreover, in this basin, FADs are placed at sea and, in most cases, especially because of adverse weather conditions are not recovered. As a consequence, Abandoned, Lost or otherwise Discarded Fishing (ALDFG) often derive from FADs. It has been estimated that approximately 1.6 million FADs were abandoned in the Mediterranean Sea between 1961 and 2017 (about 60,000 FADs every year) (Sinopoli et al., 2020). While the largest fishing areas are off Malta (34,465/km2) and Tunisia (23,033/km2), the greatest numbers of abandoned plastic sheets (452,742) and concrete blocks (905,483) were estimated to be around Tunisia, while the greatest amount, in terms of length, of polyethylene cable (399,423/km2) was estimated to be around Sicily.

Research to assess effects on the benthic fauna in an area of the central Mediterranean Sea exploited by fisheries using fish aggregating devices (FAD) demonstrated that Derelict fishing gear, mainly FAD ropes, represented the main source of marine debris, contributing 96.2% to the overall litter. 47% of debris items (mostly FAD ropes) entangled colonies of the protected black coral Leiopathes glaberrima but also other benthic communities such as hydroids (Sertularella gayi), sponges, and sea urchins (Cydaris spp.) (Consoli et al., 2020).

Overall, reducing the number of FADs and introducing new types of FADs equipped with specific technological systems appear to be the most suitable strategies to mitigate the impact of FADs on the environment and resources, as well as measures and incentives to involve fishermen in their better management. Good practices have been adopted in Sicily (De Domenico et al., 2023) for reducing and managing marine litter coming from fisheries, using anchored FADs. However, policies remain difficult for fishermen to apply, compromising the efforts made by local communities to address effects on the environment, with consideration to the local socio-economic context. The importance of all fishery stakeholders and policy makers to work together has become critical, in addition of proposing new tools for improving management measures in the study area. Recent developments have shown that fully sustainable FAD have been proposed (De Domenico et al., 2023) and could be transferred to other Mediterranean areas to limit their impacts and improve sustainability of the fishing mode.

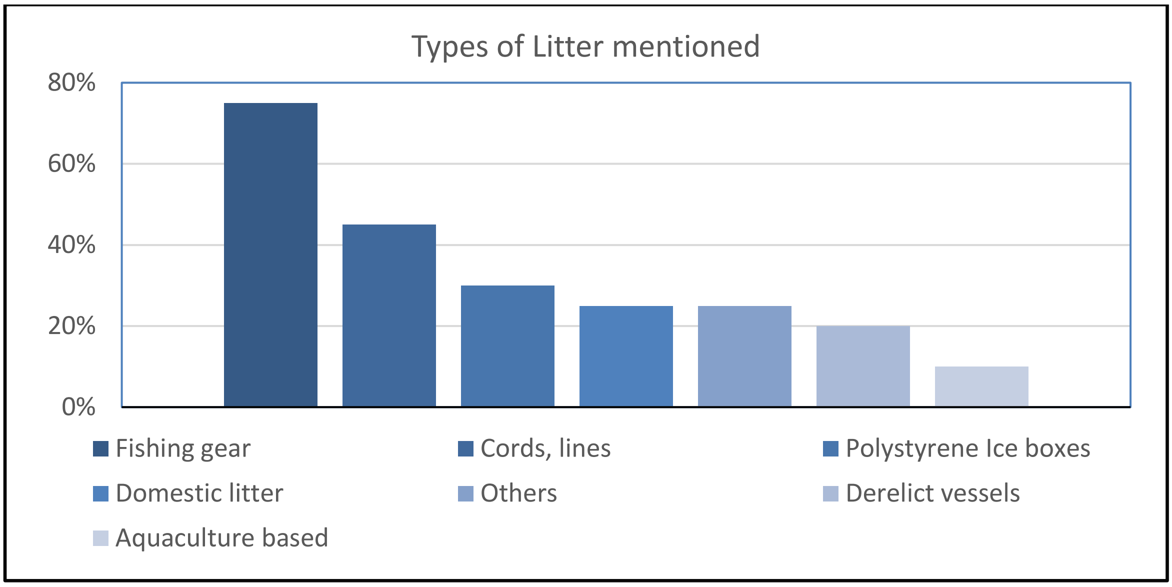
CASE STUDY 2:
Stakeholders' perception of waste from fishing vessels in Mediterranean

*In an online survey (**Annex 1**) conducted between January and February 2025 among a range of stakeholders, including fishers (3), fishery (1) and environmental (10) managers, scientists (4), and civil society (2) from Mediterranean countries, the main types of waste and fishing gear observed were analysed, along with the reduction measures mentioned by the respondents. Despite a limited number of responses (20) from 10 countries (Greece, Italy, Tunisia, Egypt, Palestine, Spain, Bosnia and Herzegovina, Libya, Israel, and France), the data analysis allowed for the identification of key insights into stakeholder perceptions.*

*The issue of waste from fishing was considered non-significant by 15%, moderate by 40%, and serious by 55% of observers, respectively. The issue was perceived as decreasing by 15%, remaining unchanged over time by 45%, and increasing by 40% of observers. 75% of the observed accumulation areas were within territorial waters, whereas 25% were in offshore waters. If fishing gear, in general, is most frequently mentioned by observers (75%), other types of fishing-related waste, such as ropes and lines, are also reported (45%). Surprisingly, the presence of fish ice boxes and abandoned vessels appears to be a significant issue among the consulted observers (**Figure 7A**). Regarding the details of fishing-related waste, gillnets, longlines, and seines are the most frequently reported debris (**Figure 7B**), whereas waste from trawling or the use of traps, pots, and cages appears to be more localized.*

Reefs, rocky habitats, and ports near fishing grounds (30% of cited areas), straits such as Messina and Gibraltar (10% of cited areas), and specific locations (e.g. Corfu area, North Tirenian, Alto Tirreno, Al Max in Egypt, deep area of the Ligurian Sea) were identified.

45% mentioned specific zones for collecting fishing gear. Additionally, 55% mentioned onshore infrastructure for managing marine litter, not specifically limited to litter from fishing, however.
In terms of management, measures were mentioned by 60% of respondents, more often through projects rather than the long-term implementation of measures. These include Awareness campaigns (20%), Regulations other than those from the EU (20%, e.g. restrictions in MPAs), EU-funded measures, mainly for EU countries (20%, e.g., EU Fund for Fisheries, EU Directive 2019/204, EU Common Fisheries Policy, EU projects, etc.), litter collection schemes (20%), Recycling & reuse initiatives (20%), and monitoring (10%).



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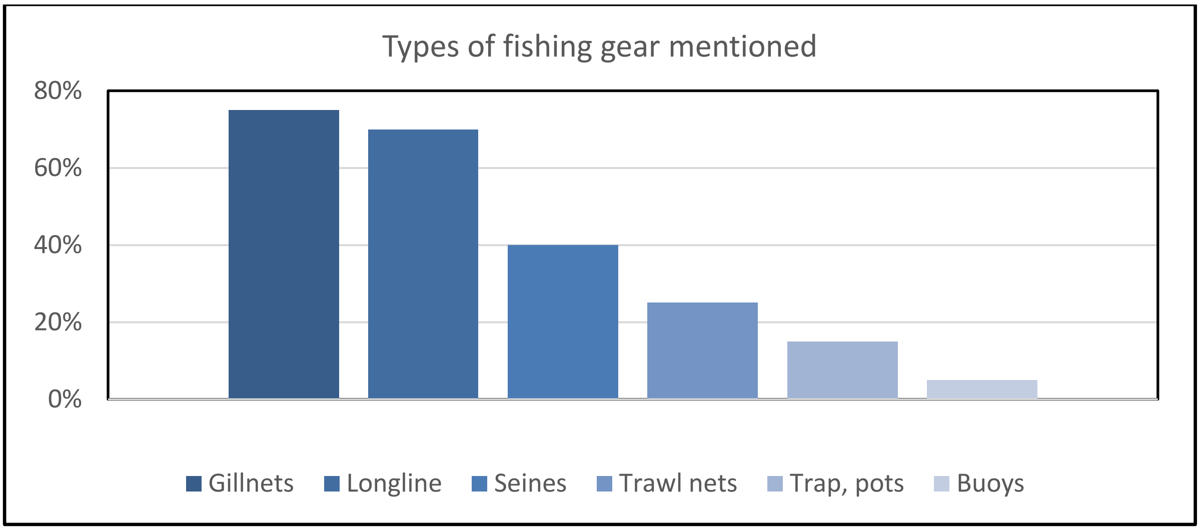

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Figure 7. Results of the survey conducted among fishers, managers, scientists, NGOs, and civil society in the Mediterranean. (A) Mentions of the types of waste observed at sea by the respondents. (B) Mentions of the types of fishing gear observed by the respondents.

4 IMPACTS OF WASTE FROM FISHING VESSELS: A FOCUS ON THE MEDITERRANEAN SEA

Marine litter from fishing vessels, particularly ALDFG, has become a significant environmental challenge, causing notable ecological, socio-economic, and biodiversity impacts. This issue is especially concerning as fishing gear, by design, is meant to interact with marine life, making its presence in the marine environment exceptionally harmful when it goes unmanaged. From ghost fishing to habitat degradation, the consequences of marine litter from fishing activities are widespread, multifaceted, and demand attention.

ALDFG poses unique threats to marine ecosystems. Ghost fishing, where derelict gear continues to ensnare and kill marine organisms, is among the most well-documented impacts. Such gear not only traps commercial and threatened species but also alters species distribution, including potentially facilitating facilitating the spread of invasive alien species and harmful algal blooms. Benthic habitats, including coral reefs and rocky substrates, are particularly vulnerable. ALDFG that sinks to the seafloor smothers corals, causes physical damage, and contributes to habitat loss, leading to cascading effects on marine biodiversity and ecosystem functionality. Moreover, the retrieval of ALDFG can further exacerbate habitat damage, highlighting the complexity of addressing this issue.

The socio-economic ramifications of marine litter from fishing vessels are equally troubling. Coastal communities bear significant financial burdens from clean-up initiatives and tourism losses. Recreational opportunities and the aesthetic value of marine and coastal areas are also diminished, impacting quality of life and local economies. For example, ALDFG can compromise ecosystem services vital to coastal livelihoods, creating a direct link between environmental degradation and economic hardship.

The documented impacts of marine litter on wildlife are serious, with rising incidences of entanglement and ingestion. Despite its importance, quantifying ALDFG's impact is challenging due to variable data collection methods and limited observations of affected species. Claro et al. (2019) reported interactions with nearly 1,400 species worldwide. However, many cases go unrecorded as carcasses often sink or are consumed by predators.

4.1 Entanglement

Entanglement and ingestion are the primary ways marine organisms are affected, with entanglement posing a particularly severe threat. ALDFG accounts for nearly all entanglements in cetaceans, primarily from pot lines and nets (NOAA, 2014 & 2015). Entanglement often leads to wounds, secondary infections, starvation, and death (NOAA, 2014; Kühn et al., 2015).

Globally, ghost gear entanglement affects 100% of sea turtles, 66% of marine mammals, and 50% of seabirds, with over 5,400 individuals from 40 species recorded as entangled or associated with ghost nets (Stelfox et al., 2016). Parton et al. (2019) reported entanglement data from the literature and social media on 34 species of elasmobranchs in all three major ocean basins, with ghost fishing gear being the most common entangling object (74% of animals), followed by polypropylene strapping bands (11%). However, only two records were mentioned on social media for this taxon in the Mediterranean.

Between 1997 and 2015, reported incidents of marine wildlife entanglement doubled, rising from 267 to 557 species (Kühn et al., 2015). ALDFG entanglements restrict movement, hinder feeding, and cause injuries that can lead to secondary infections or death (NOAA, 2014 & 2015). A 2018 report by SPA/RAC (UNEP MAP, 2018) highlighted that 72% of global observations of entanglement were caused by abandoned fishing gear, with human product packaging being the second most common source.

Entanglement causes severe direct effects, such as injuries, restricted mobility, severed arteries, suffocation, and death from drowning or predation in vertebrates, as well as broken branches and reduced mobility in benthic invertebrates like corals. Indirect effects, including diminished ability to feed, reduced fitness, impaired reproduction, and vulnerability to predators, jeopardize survival. For example, entangled nesting sea turtles with flipper amputations may fail to dig nests successfully, impacting population stability (Sanchez- INDICIT II, 2021).

In a study on species sensitivity of 31 species (mammals, birds, and turtles), Høiberg et al. (2022 & 2024) calculated the Number of individuals affected (% of the population) by entanglement in marine species as a function of litter concentration, and cross-mapped the observed entanglement rates of species from all ocean basins with surface macroplastic debris concentration datasets, enabling the mapping of risks for various species to become entangled. For three common Mediterranean species, the authors found that 5 kg/Km2 of debris will entangle more than 20% of the population of *Morus bassanus* (gannet), while 10 kg /km2 will affect 40% of the *Caretta caretta* (sea turtle) population, and 100 kg/km2 of litter will entangle more than 80% of the *Tursiops tursiops* population

Similarly, Anastasopoulou and Fortibuoni (2019) showed that 44 Mediterranean species were found entangled in marine litter. In the Tyrrhenian Sea, ALDFG, particularly longlines, has caused significant damage to coralliferous biocenosis, with 49.1% of recorded impacts occurring at depths of 41–80 meters (Consoli et al., 2019). These impacts are compounded during ALDFG retrieval, as removal efforts can cause fragmentation, abrasion, and tissue damage to already-affected corals (Consoli et al., 2019). Monofilament lines, a common component of ghost gear, severely degrade coral colonies, leaving them with higher mortality rates compared to areas without such gear (Galgani et al., 2018).

ALDFG also serves as a platform for invasive species, including pathogens, to settle and colonize. Floating litter items, including ALDFG, have been linked to the spread of harmful organisms that disrupt marine ecosystems (Edwards et al., 2020). This amplifies the environmental damage caused by ghost gear and highlights its multifaceted ecological impacts.

4.2 Ghost Fishing and Loss of Biodiversity

ALDFG has well-documented significant adverse effects on marine ecosystems, with ghost fishing being one of the most critical impacts (Figure 8). Ghost fishing occurs when derelict gear continues to catch and kill marine organisms, including commercially valuable and threatened species, usually for months after being abandoned. The consequences extend beyond direct mortality to altering species distributions, facilitating the spread of invasive species, and supporting harmful algal blooms through floating debris (Gilman et al., 2023).

Lost fishing gear, including gillnets and pots, retains its ability to trap marine life, often indiscriminately. UNEP (2021) documented hundreds of species entangled in derelict fishing gear, including mammals, birds, finfish, and invertebrates. Similarly, derelict pots from recreational fisheries cause extensive mortality; Antonelis et al. (2011) estimated over 110,000 harvestable Dungeness crabs lost annually to abandoned pots in the same area. Bilkovic et al. (2014) and VIMS (FAO, 2019c) found that blue crab traps along the U.S. East Coast and Gulf of Mexico capture both target and non-target species, including those vital for commercial and recreational fishing.

The prevalence of ghost fishing varies across regions. For example, Angiollilo et al. (2023) observed that only 11% of fishing nets along the Italian coast were potentially involved in ghost fishing. Experimental studies in the Aegean Sea revealed that the effectiveness of monofilament and multifilament gillnets decreases significantly over time due to colonization and structural degradation, with multifilament gillnets collapsing completely within a year (Ayaz et al., 2006). Despite these patterns, not all ALDFG contributes to ghost fishing (Tubau et al., 2015; Angiollilo et al., 2021).

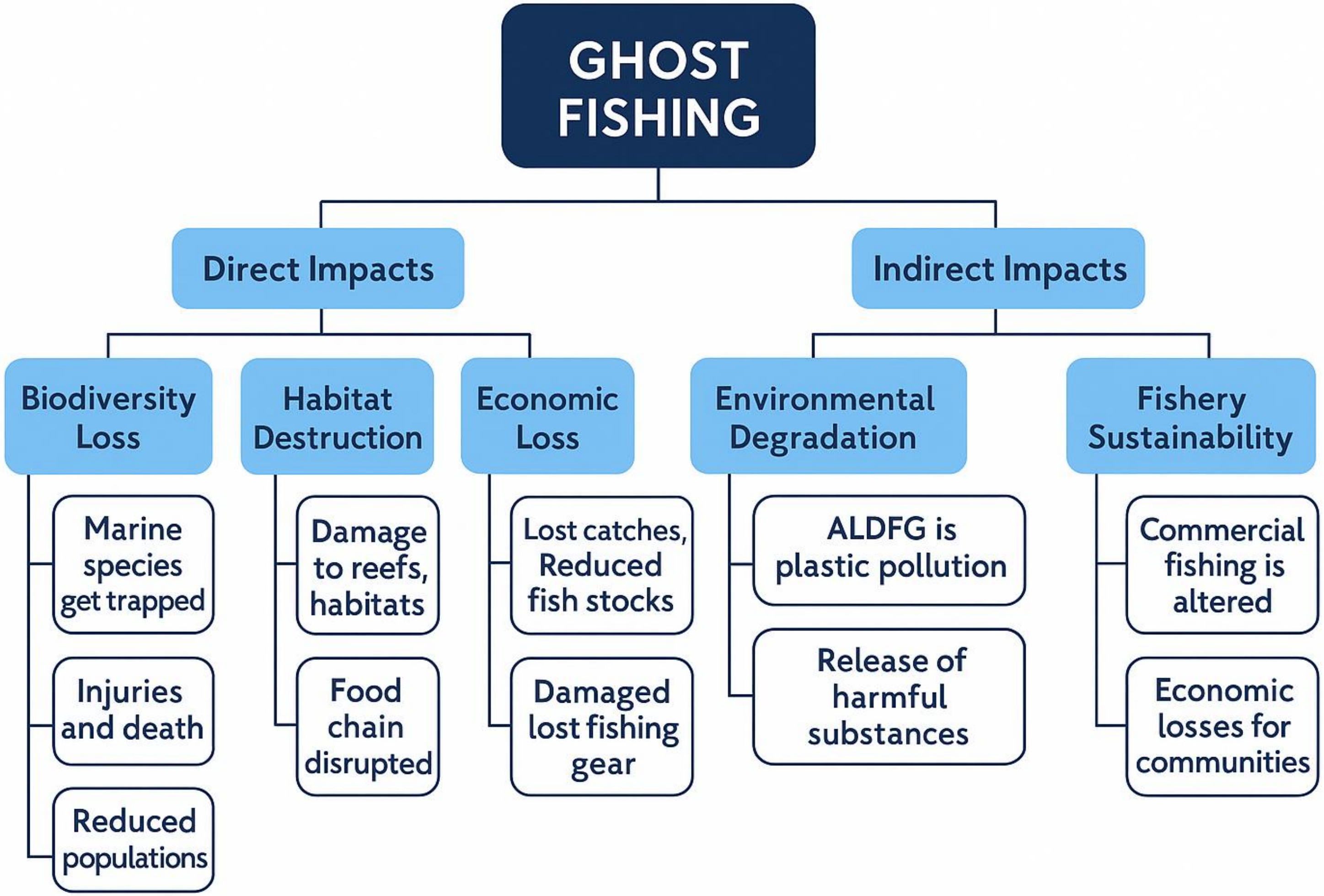

Figure 8. Key impacts of the ghost gears (modified from Wasave et al., 2025)

ALDFG has far-reaching impacts, including disrupting trophic chains and cascading ecological imbalances by removing key species like apex predators (Thushari and Senevirathna, 2020). Retrieval efforts have demonstrated the scale of the problem; McIntyre et al. (2023*)* reported removing over 29,000 kg of ALDFG in Canada, including traps up to 37 years old, which continued to catch both target and non-target species. However, determining whether ghost fishing mortalities result from ALDFG or active gear remains challenging (NOAA, 2014). The INDICIT II Consortium (2021) noted that entanglement data rarely distinguish between these sources, emphasizing that gear abandoned at sea becomes marine litter, contributing to ongoing ecological damage. These findings underscore the urgent need for effective mitigation strategies to address the widespread impacts of ALDFG.

4.3 Other impacts from ALDFG

Waste from fishing vessels, including ALDFG, has significant environmental impacts that extend beyond entanglement. It interacts with marine species in various ways, such as ingestion, coverage, transport, incorporation into habitats, use as alternative substrates, and behavioural interactions (Angiolillo and Fortibuoni, 2020).

Ingestion: While less harmful than entanglement, ALDFG is known to harm marine megafauna through ingestion (GESAMP, 2021), with drift nets generally presenting the highest risk (Gilman et al., 2021). Additionally, ingestion of ALDFG components, such as pieces of nets and ropes, hooks, and lead sinkers, causes toxicity and life-threatening internal injuries in birds, turtles, and fish, often leading to gastrointestinal perforation, toxicity, and starvation (INDICIT II, 2021). For instance, Saturno et al. (2020) examined 216 gastrointestinal tracts of Atlantic cod (*Gadus morhua*) caught by commercial fishers and found 1.4% to contain intact bait bags used in commercial potting or polypropylene thread, likely originating from fishing rope. In 2019, Anastasopoulou and Fortibuoni (2019) recorded in the literature that, in the Mediterranean Sea, 116 species were reported to have ingested plastic.

Microplastics: Fishing nets may release hundreds of microplastic pieces per meter (Wright et al., 2021), and FRP vessels, a component of waste from fishing vessels, also contribute to the presence of microplastics and their impacts (GESAMP, 2025). Evaluating the proportion of microplastics coming from ALDFG or other plastic waste from fishing vessels is not well-documented, but it may correspond to the percentage of the fishing fleet within the total world tonnage of vessels made of plastic polymers. Thus, the contribution to harm caused by the ingestion of microplastics (GESAMP, 2016) could be highly significant, noting that microplastics from ALDFG generate fibrosis and disrupt feeding mechanisms (Garnier et al., 2021).

Habitat Degradation: A critical impact of ALDFG is the degradation of habitats and ecosystems, which indirectly affects marine sustainability (Beaumont et al., 2019; Wassave et al., in press). When ALDFG accumulates on the seafloor, it smothers benthic communities, leading to widespread mortality of corals and other organisms. Studies have documented severe coral damage in Thailand, where 143 pieces of ALDFG caused extensive tissue loss and fragmentation in over 1,500 corals (Ballesteros et al., 2018). Similar damage has been observed in the Ligurian and Tyrrhenian Seas, where lost fishing gear has harmed gorgonians and coralligenous habitats (Consoli et al., 2019). Efforts to remove ALDFG can exacerbate damage, further fragmenting corals and causing additional tissue injury (Consoli et al., 2019). The smothering effect of ALDFG can also impede recolonization, reduce gas exchange, and deprive benthic organisms of essential light and oxygen, ultimately weakening ecosystems (Galgani et al., 2018; Wasave et al., in press).

Transport of Invasive Species: Floating ALDFG can serves as a substrate for invasive species and microalgae, facilitating their transport across ecosystems. These species may contribute to harmful algal blooms, altering native species distributions and ecosystem dynamics (Gilman et al., 2023). Drifting fishing aggregating devices (FADs) can also modify the behaviour, diet, and reproduction of aggregated organisms, further disrupting biological systems.

Substrate and Incorporation: ALDFG acts as an alternative substrate for sessile organisms, particularly in benthic ecosystems like coral reefs and gorgonian habitats (Angiolillo and Fortibuoni, 2020). In some cases, marine debris becomes physically incorporated into coral frameworks, as documented in Mediterranean ecosystems (Angiolillo et al., 2021). Such incorporation disrupts natural growth patterns and habitat functionality.

4.4 Impact of waste from fishing vessels in the Mediterranean Sea

The Mediterranean, as a semi-enclosed basin, is one of the most polluted marine environments, with significant pressure from marine litter on living organisms (UNEP MAP, 2015a*)*. Marine litter in the Mediterranean effects species that are vulnerable or even classified as endangered to varying degrees, underscoring the importance of effective and targeted marine litter management *(*Angiolillo and Fortibuoni, 2020; Perroca et al., 2024). For instance, two endangered species—the red coral *Corallium rubrum* and the madrepora coral *Madrepora oculata*—were among the 78 benthic taxa observed interacting with marine litter, primarily ALDFG (Angiolillo and Fortibuoni, 2020). Similarly, vulnerable and endangered marine vertebrates, such as marine turtles (*Chelonia mydas* and *Caretta caretta*), which breed in the basin, are also affected.

Identifying interactions specifically attributable to fisheries-related litter poses significant challenges. For marine vertebrates, entanglement is the primary interaction traceable to fishing gear. However, it is often difficult to confirm whether the material involved is litter (see above). Ingestion of marine litter, particularly microplastics, is well-documented across a wide range of Mediterranean marine organisms. Still, distinguishing litter specifically originating from fisheries remains nearly impossible.

The seafloor serves as the ultimate sink for most marine litter, with processes like biofouling increasing the likelihood of items sinking (see Canals et al., 2021 and references therein). As in other oceans, marine litter on the Mediterranean seafloor—primarily ALDFG—can interact with, damage, or even kill marine organisms (**Table 5**).

Entanglement: Data related to the number of species specifically impacted by ALDFG mainly concern epibenthic invertebrates. However, a recent study employed a new approach to complement data published in the literature (Perroca et al., 2024), comprehensively investigating the impacts of ghost nets on the Mediterranean's aquatic ecosystems using a total of 113 videos collected from digital media. The data documented ghost net entanglements in 86 species across 12 Mediterranean countries (Perroca et al., 2024). While reliance on digital media presented certain limitations, such as the inability to ascertain the precise characteristics of ghost nets, it also offered unique advantages, including broad geographic coverage and access to information about otherwise inaccessible events. The entangled organisms ranged from algae and invertebrates to vertebrates, encompassing a wide array of biodiversity.

Ten species were identified as threatened according to the IUCN. The data highlighted fish and large crustaceans as the most frequently entangled groups (*Epinephelus marginatus, Palinurus elephas*), along with sea turtles.

Table 5. Analysis of the scientific literature addressing interactions between Fishing gear and marine organisms in the Mediterranean Sea

COUNTRY[2]	ZONE	DEPTH	METHOD	MAIN TYPES OF FISHING GEAR	% OF LITTER WITH INTERACTIONS	TYPES OF INTERACTIONS	SPECIES INTERACTING WITH FISHING RELATED ITEMS	REFERENCES
Türkiye	North eastern Mediterranean Sea	19-194 m	Trawling		NC (trawling)		Colonisation by Mollusca, Porifera, Cnidaria, Bryozoa, Annelida, Arthropoda, and Chordata	Gonudal et al. (2024)
Israel	Coastal areas	20-1600 m	Trawling	Ropes, nets, fishing lines, and boat rust	NC (trawling)	Fouling	Fouling by molluscs, Polychaeta, Cnidarian and Crustacea	Segal & Lubinevsky (2023)
Greece	Saronikos Gulf	96–115 m	ROV/video	Monofilament and entangled fishing lines, synthetic ropes, fishing nets	75 % of litter items with interactions with benthic megafauna	No record of entanglement	DFG fouled by Polychaeta, Echiura, Gastropoda, Tunicates, Bivalvia, cnidaria, Algae	Ioakeimidis et al. (2015)
Italy	Northern Adriatic	10-50 m	Trawling	Mussel socks (29%), trawl nets (27%), cables	NC (trawling)	Mainly mussel socks and nets are fouled	Colonized by polychaetes, molluscs, algae, Tunicates Bryozoan,	Mistri et al. (2024)
Italy	North Western Adriatic	20-25 m	ROV/ Video	Ropes (62%), nets (18%), trawl liners (14%), also mussel sock	84% of gillnets, 76,9% of ropes / wires, and 76.9% of trawl nets with interactions	Entanglement/ Coverage at 66% of litter; 70% of the items highly fouled (>50.0% of their surface)	Fouling mainly by Porifera, cnidaria and Tunicates'	Melli et al. (2017)
Italy	Tunisian-Sicilian channel	20-220 m	ROV/ video	Lines (85%) and ropes	29.79% of ALDFG causing entanglement/coverage; & 9,2% colonized	Line & ropes (entanglement); ropes & nets (colonisation)	Cnidarians/ sponge (entanglement coverage); hydroids, algae and ophiuroids gorgonian (Eunicella sp.) for colonisation	Consoli et al. (2018)

[2] Countries are listed from east to west to facilitate comparison by basin

South Malta	Tunisian-Sicilian channel	250-400 m	ROV/ video	83 % FAD	47,50%	47% entanglement, 42% hanging litter	94% by anthipatharia (*Leiopathes glabberima*)	Consoli et al. (2020)
Italy	Gulf of Policastro	100-600 m	Pole trawling	Fishing lines, pieces of net	NC (trawling)	14% of the litter items fouled by megafauna,	Colonization: Annelida Bryozoa, Mollusca	Rizzo et al (2024)
Italy	Liguria	30-216 m	ROV video	Fishing lines, nets and ropes for 67, 17 and 11% of ALDFG			Colonization by coralligenous algae, sponges, hydrozoans, alcyonaceans, serpulids and bryozoans	Enrichetti et al. 2016
Italy	Aeolian islands	15-411 m	ROV Video	Fishing lines and ropes	10.6% of litter items showed interactions with species	Entanglement + coverage by trawl nets; encrustation and colonization by sessile organisms	Colonised by corals, gorgonians, sessile organisms for coverage	Consoli et al. 2021
Italy, Monaco, France	Ligurian sea, Cote d'Azur	340–2200 m	ROV/ Video	Fishing lines, no ghost fishing	70% of litter have interactions	59,4% of ALDFG colonized, 8,7 % of interactions is entanglement	Colonisation by porifera, cnidaria, polychaetes, bryozoan,	Angiolillo et al. (2021)
Spain	Catalunya/ canyons	140 – 1731 m	ROV/ Video	Long lines, nets	NC (trawling)	Entanglement (monofilaments and long lines)	Colonisation (lines, nets) by polychaetes, Cnidaria (deep sea), entanglement of cnidaria, echinoderms Lost nets used by fishes and crustaceans as hideouts	Tubau et al. (2015)

Entanglement events were most prevalent in Italy and Türkiye, reflecting their extensive coastlines and intensive fishing activities within the Mediterranean. Other significant regions included Greece, Spain, and Algeria. The findings underscore the severe ecological impacts of ghost nets at various trophic levels. Vulnerable species also face heightened threats due to habitat degradation and direct mortality from entanglement. Megafauna, such as whales and sharks, were particularly susceptible due to their size and behaviour, which often led to fatal encounters with ghost gear.

A survey performed as part of the EU project INDICIT identified that ALDFG (lines, trawls, nets, and ropes) entangled at least three species of marine mammals (*Stenella coeruleoalba, Tursiops truncatus, Physeter macrocephalus*) (Attia el Hili et al., 2018), with dolphins and sperm whales most often found stranded. The number of observations per year was low, except for *Stenella coeruleoalba* in Greece, where 30% of 120 specimens were found entangled every year (Attia el Hili et al., 2018), mainly in nets. In the northern Aegean Sea (Milani et al., 2017*)*, the prevalence of entangled *Phocoena phocoena* was 28.5%, though this was based on a limited number of samples (seven samples).

The same project showed that Spain and Greece are hotspots of loggerhead and green sea turtle entanglement by fishing gear (Table 6). In Greece (Rhodes), between 1984 and 2011, 11% and 14% of stranded or rescued loggerheads and green turtles, respectively, were entangled in fishing gear material (Corsini-Foka et al., 2013). Between 2012 and 2017, 9% and 21% of stranded or rescued loggerhead and green turtles, respectively, were entangled. Offshore Valencia (Spain), 70% of the 38 loggerhead turtles observed between 1995 and 2017 were found entangled in ALDFG. However, as a common issue, it was difficult to distinguish between fragments of active gear (fragments cut after bycatches) and litter.

In the Mediterranean, Colmenero et al. (2017*)* reported cases of juvenile blue sharks (*Prionace glauca*) entangled in plastic straps around their gill region, causing varying degrees of injury to the dorsal musculature and pectoral fins. Straps are often used for the packaging of fish bait. Some fishermen, therefore, began cutting the straps before, unfortunately, throwing them into the sea anyway (Attia el Hili, 2018; Gilman et al., 2023). It is, therefore, possible that such interactions with straps are under-reported in the Mediterranean.

Epibenthic Invertebrates: On the seafloor, DFG (derelict fishing gear) is often the primary source of marine litter and may represent up to 98% in Italy (Consoli et al., 2018, 2019, 2020, 2021; Table 5), interacting with benthic organisms. There is a direct link between entanglement in epibenthic invertebrates and the spatial distribution of fishing efforts, particularly in fishing grounds where longlines and gillnets are used, whereas epibenthic organisms are left dead after trawling operations (Attia El Hili, 2018).

Table 6. Feasibility of an entanglement indicator in sea turtles (After Attia el Hili et al, 2018I, Bentivegna et al, 1995, Corsini-Foka et al, 2013, & data from RTMMF) (AS) at-sea, (OL) on land, (AE) Aerial, (DEB) marine litter of user origin, such as plastic package, baler twine (rafia etc.) or other (stake nets etc.…), (FG) fishing gear: (L) lines (long lines & monofilament line pieces, hooks…), (N/T) pieces of nets or trawl nets, (R) piece of single rope (mooring, pot etc.) (L) lesion, (CD) carapace distortion, (A) Amputation, (D) death, (yr.) year. References in italics indicate that datasets were available.

SPECIES	COUNTRY/ OCEANIC BASINS	DATE	TYPE	N	NUMBER ENTANGLED (%)	CIRCUMSTANCEs	ITEM/ MMATERIAL	EFFECT
LOGGERHEAD TURTLE *Caretta caretta*	France (Mediterranean)	2010-2016		103	9 (8.7%)	AS, ON	FG, DEB	NA
	Türkiye	NA	Dead	38	12 (31.6 %)	OL	DEB	A
	Tunisia (Strait of Sicily)	2013	Alive	NA	1	AS	FG (L)	L, CD
	Italy (Tyrrhenian Sea)	NA		NA	1	AE	DEB, FG (N/T)	NA
	Italy (Sicily)	1994	Alive	NA	1	AS	DEB, FG (R)	
	Spain (Mediterranean)	1994-2017	Alive, Dead	1415	38 (2.7%)	OL, AS	DEB, FG (L, N, R)	L
	Greece (Rhodes Island)	1984-2011	Alive, Dead	152	17 (11%)	OL	FG (L)	
	Greece	2012-2017	Alive, Dead	79	7 (8.8%)	OL	FG (L)	L, A, D
LEATHERBACK TURTLE *Dermochelys coriacea*	Spain (Mediterranean)	1994-2017	Alive	10	1 (0.1%)	OL	FG	NA
GREEN TURTLE *Chelonia mydas*	Greece	2012-2017	Dead	14	3 (21.4%)	OL	FG (L), DEB	L, D
	Greece (Rhodes Island)	1984-2011	Alive, Dead	42	6 (14%)	OL	FG	

Most information on the entanglement of epibenthic invertebrates is opportunistically obtained from videos. In the Mediterranean, entanglement has been documented in several countries *(*Table 5*)*. Typically, the most frequently entangled taxa by ALDFG are Porifera and Cnidaria, with Bryozoa and Arthropoda affected to a lesser extent (Angiolillo and Fortibuoni, 2020). In corals, especially arborescent species and cold-water corals, entanglement in derelict fishing gear is very common. Continuous mechanical friction from gear can cause the breakage of coral ramifications or progressive tissue removal, making corals more vulnerable to parasites or bacterial infections (Carvalho-Souza et al., 2018). Abrasion and coenenchyme loss are, however, the most common effects of entanglement in Mediterranean animal forests. Necrosis and epibiosis are widely reported, as well as direct damage such as broken branches, detachment from the seafloor, and death. Larger colonies, arborescent morphologies, and flexible skeletons are the most affected.

Coverage (Smothering): Coverage or smothering, which affects benthic sessile organisms, has been described in the Mediterranean, with ALDFG as the primary cause. Cnidaria and Porifera are the most exposed taxa (Table 5).

Colonization and Encrustation: In the Strait of Messina (Italy), Battaglia et al. (2019) observed the colonization of rafting floats from ALDFG by four protected deep-sea species: *Errina aspera, Desmophyllum pertusum, Madrepora oculata,* and *Pachylasma giganteum.* Between 2016 and 2019, the authors found 41 floats colonized by deep benthic species stranded on the Sicilian coast of the Strait of Messina, on which 3,014 deep-water organisms were counted, belonging to 38 taxa of macro-invertebrates (*Foraminifera, Porifera, Cnidaria, Anellida, Mollusca, Arthropoda,* and *Bryozoa*). The frequency of occurrence of these macro-invertebrate taxa ranged from 2.44% to 73.17%. Based on the species assemblages, their ecology, biogeography, and patterns of water circulation, the origin of colonized floats was determined to be the Strait of Messina.

In the Tunisian-Sicilian channel (Ragusa Bank), Cattaneo Vietti et al. (2017) documented the illegal and continuous use of this fishing gear for red coral (*Corallium rubrum*). During the ROV survey, the authors recorded three lost pieces of gear showing different levels of colonization, depending on the duration of their immersion.

In the Mediterranean Sea, total coverage may be reached in only one year (Enrichetti et al., 2021), depending on light availability, with algae and hydrozoans settling in less than two weeks, followed by bryozoan within a few months. The authors propose that biofouling could be used to estimate the age of lost lines and nets in retrieved material, while in-situ photo footage provides a better evaluation of the impact of fishing gear.

Habitat Degradation: Moschino et al. (2019) demonstrated that both natural and artificial hard substrates along the Veneto coastline are significantly impacted by derelict fishing gear. Through mapping and removal efforts, approximately 350 pieces of fishing gear and related waste were collected from eight natural rocky outcrops and an artificial reef. Considering that an estimated 3,000 rocky outcrops exist in the Gulf of Venice, Moschino et al. (2019) estimated that up to 60,000 ALDFG items could be present on the rocky seabed in this area. Although the number of organisms caught through ghost fishing was negligible, the removal of abandoned nets and fishing gear had a positive effect on the health of rocky outcrop ecosystems. Moschino et al. (2019) confirmed that ALDFG negatively impacts benthic and fish communities by altering the microhabitat, occupying and covering parts of the substrate and organisms, and obstructing reef crevices.

Substratum: Marine litter can serve as an alternative substratum for sessile species on Mediterranean reefs. Cnidarian species may grow on fishing gear, as well as *Annelida, Echinodermata, Mollusca,* and *Porifera* species (Angiolillo and Fortibuoni, 2020). In another example from the Blanes Canyon (Spain), Aymà et al. (2019) reported the presence of *Desmophyllum pertusum* colonies growing on nylon net cords at 752–864 m depth in the Blanes Canyon (Western Mediterranean). While this colonization illustrates the adaptability of marine organisms, it also presents a management dilemma: the removal of such litter or ghost gear may risk damaging the very species that have settled on it, including vulnerable or protected taxa such as corals. This highlights the need for careful assessment and mitigation strategies when planning removal operations in sensitive habitats.

Incorporation: Derelict fishing material has been observed incorporated into benthic organisms and colonies in the Mediterranean (Angiolillo and Fortibuoni, 2020; **Table 5**). In the Apulian Ridge in the Ionian Sea, Savini et al. (2014) observed litter incorporated into the skeleton of living coral colonies. Angiolillo and Canese (2018) described fishing lines incorporated in the yellow scleractinian *Dendrophyllia cornigera* in the Ligurian Sea. In the Tremiti Islands, Chimienti et al. (2020) observed a cable within a group of *Antipathella subpinnata* colonies.

Behavioural: The most common example could be the use of fishing pots by cephalopods. However, the high availability of marine litter may result in changes in the behaviour of reef species, including fish and crabs, which may use litter as shelter instead of natural materials (Angiolillo and Fortibuoni, 2020). In the Western Mediterranean, Pierdomenico et al. (2018*)* reported a case of a squat lobster (*Munida spp.*) found hidden in lost fishing gear.

4.5 Other Impacts Caused by Waste from Fishing Vessels

Other marine debris from fishing vessels may impact wildlife and ecosystems, including plastic bags containing salt used to make brine, plastic-lined boxes, plastic packing straps used for frozen bait, and liquid wastes such as oil, sewage, cargo nets, anti-fouling paint particles, bilge water, and ballast water (Gilman et al., 2023). Toxins and microplastics from gear and non-gear fishing debris, as well as from paints or degrading FRP fishing vessels, may be distributed and transferred into marine food webs at various trophic levels, from zooplankton to large pelagic fishes (Gilman et al., 2023).

FRP Vessels: Abandoned and derelict vessels (ADVs) present significant environmental and safety challenges, despite the vital services vessels provide for recreation and commerce. ADVs contribute to pollution through oil spills, microplastics, and hazardous material leaks while obstructing navigation, damaging habitats, and deterring tourism. Many vessels are constructed with fibre-reinforced plastic (FRP), which, along with other hazardous components like electrical fittings and metals, poses environmental threats (GESAMP, 2025). Unlike maintained vessels, abandoned vessels deteriorate uncontrollably, necessitating mitigation efforts to address their environmental impacts.

Environmental concerns at sea are particularly acute in marine settings. Abandoned fishing vessels can physically damage sensitive marine habitats, such as coral reefs and seagrass beds, through smothering, crushing, or displacement. The gradual breakdown of FRP into microplastics and glass fibres introduces persistent pollutants into the ecosystem, harming marine organisms through ingestion, entanglement, or physiological stress (GESAMP, 2025).

Moreover, misguided attempts to repurpose FRP vessels as artificial reefs may worsen the problem, as the material is prone to fragmentation and dispersal by ocean currents, compounding marine pollution.

These impacts highlight the need for improved end-of-life vessel management strategies, particularly for small-scale fishing fleets, and for stricter controls on the disposal of vessel components and associated waste.

Onshore disposal of FRP fishing vessels also raises environmental concerns. Landfilling, though common, consumes substantial land resources and can produce hazardous leachates. Burning FRP materials, another disposal method, releases harmful pollutants like arsenic, benzene, and dioxins, posing health and ecological risks. Despite efforts to mitigate the environmental impacts of vessel disposal, significant challenges remain. Replacing hazardous materials with sustainable alternatives in vessel construction can help reduce long-term environmental harm.

Impact of Microplastics: The problem of microplastics in marine environments is increasingly linked to a variety of sources, including ALDFG, other plastic waste from fishing vessels, degrading fiberglass-reinforced plastic (FRP) vessels, and paint particles. Among these, paint particles, especially from antifouling (AF) coatings, are emerging as a significant concern. Studies by Cardozo et al. (2018) highlight that up to 63% of plastic particles found in certain fish species originate from paint, mainly from fishing vessels. Despite this, research on the environmental impact of paint particles remains limited.

Experimental studies reveal the acute toxicity of AF paint particles, particularly those with biocidal properties such as copper. Modern AF paint particles are notably more toxic than older ones due to higher concentrations of harmful agents. These particles pose severe risks to sediment-dwelling organisms like worms and molluscs, with chronic exposure effects observable at levels far below lethal concentrations. Sensitivities vary among species, with some showing greater vulnerability. Silicone-based paints, however, exhibit comparatively lower toxicity.

Soroldoni et al. (2020) observed that burrowing species might face increased exposure to sediment-bound contaminants, while Molino et al. (2019) noted that AF paint particles reduce chlorophyll A concentrations in marine environments and increase copper levels. Turner (2021) found that paint particles constitute up to 35% of synthetic micro-debris in marine environments, often containing hazardous additives that elevate their risks compared to other microplastics.

Gaylarde et al. (2021) emphasized that paint particles can be up to 30 times more prevalent than other microplastics in certain regions, the release of harmful substances like metals and polycyclic aromatic hydrocarbons (PAHs) from paint coatings, leads to significant bioaccumulation and stress responses in marine organisms. Similarly, Soon et al. (2023) identified suspended solids, metals, and biocides in hull cleaning effluents as significant threats to marine ecosystems, understanding that biocide-free coatings could significantly reduce microplastics and biocide release from fishing vessels, presenting promising solutions for sustainable maritime practices.

Finally, the gradual breakdown of FRP into microplastics and glass fibres introduces persistent pollutants into the marine environment. These materials can harm marine organisms through ingestion, entanglement, or physiological stress. Studies have documented the ingestion of fiberglass by mussels, leading to inflammatory reactions and impaired function, and identified toxic substances, including lead and other metals from FRP, contaminating marine sediments and macroalgae near abandoned vessels (GESAMP, 2025).

4.6 Economic impacts

Human activities, including overfishing, pollution, and climate change, are placing immense pressure on marine ecosystems. These anthropogenic stressors threaten not only the health and productivity of the marine environment but also the economic and nutritional benefits it provides (FAO, 2020a). As the global population grows, these risks intensify, underscoring the urgent need for sustainable and integrated management practices.

Marine litter, especially plastic pollution, is among the most pressing threats to ocean health, with plastics alone imposing environmental damages valued at approximately USD 13 billion annually (UNEP MAP, 2015a, Giskes et al., 2022). ALDFG contributes significantly to these damages, with extensive socio-economic and environmental consequences. The direct financial costs of ALDFG are substantial, including expenses incurred by fishers to replace lost gear and by governments or organizations to retrieve discarded gear from the marine environment. Indirect costs are also considerable, as ghost fishing—where lost gear continues to capture marine organisms—reduces the availability of fish stocks, diminishes future fishing opportunities, and results in the loss of revenue that might have been generated from these catches. For example, a study on derelict blue crab pots in Virginia, United States, demonstrated that the removal of these lost gear items increased crab harvests by 22.4% per pot and 34.7% per trip, leading to an 18% annual rise in productive hauls and generating an estimated USD 3 million in net annual benefits (Scheld et al., 2021).

Derelict fishing gear diminishes people's quality of life by reducing recreational opportunities, degrading the aesthetic value of natural areas, and harming non-use values like clean beaches and coastal environments (Cheshire et al., 2009). Coastal communities incur additional costs for clean-ups and prevention efforts, while tourism and associated revenue streams often suffer significant losses. Damage to marine habitats caused by ALDFG also compromises the availability and functionality of ecosystem services that are vital to coastal economies (GESAMP, 2015).

Lost gear not only results in the forfeiture of target species already captured but also continues to capture and kill marine life through ghost fishing, further reducing the fishery's long-term productivity. The financial impacts of these losses are substantial but often underappreciated due to their hidden nature. Studies have highlighted the economic toll of ALDFG on various fisheries. For instance, in Oman, research estimated that 90% of ghost-caught species in lost fish traps were of commercial value, amounting to a loss of approximately USD 168 million annually (Gesamp, 2021). In Spain's Cantabrian region, ghost fishing tangle nets were found to account for 1.46% of the area's total commercial monkfish landings, demonstrating the pervasive impact of ALDFG on local fisheries. In Washington State, United States, derelict crab pots were estimated to kill nearly 179,000 Dungeness crabs annually, representing an economic loss of over USD 744,000, or 4.5% of the value of the crab harvest (Antonelis et al., 2011).

Efforts to recover lost fishing gear can mitigate these losses, but the costs and benefits of such programs vary widely. In some cases, the expenses of retrieval outweigh the financial benefits, particularly when the value of recovered gear or prevented losses is low. For example, a study in the United Kingdom estimated that the cost of a hypothetical gillnet retrieval program would exceed the financial benefits, resulting in net costs of EUR 23,836 (Brown and Macfadyen, 2007). However, other examples highlight the potential economic advantages of gear recovery. In the United States, removing an abandoned gill net capable of causing over USD 20,000 worth of crab losses over a decade was estimated to cost just USD 1,358 (GESAMP, 2021). Moreover, fishers participating in recovery programs can sometimes directly benefit financially. For instance, in a lost gear recovery initiative, fishers received over USD 42,000 in direct payments over four years (Sullivan et al., 2019). These examples demonstrate the importance of conducting cost-benefit analyses to evaluate the trade-offs associated with gear recovery efforts and guide effective policy decisions.

In addition to its direct economic impacts, ALDFG causes broader environmental and social harms (**Table 7**). Ghost fishing contributes to habitat degradation, as lost gear can damage sensitive ecosystems such as coral reefs and seagrass beds. It also obstructs maritime industries by fouling marine vessels and damaging active fishing gear and underwater infrastructure, including submarine cables. Furthermore, ALDFG reduces the recreational, aesthetic, and tourism value of coastal and marine areas, which can have significant socio-economic repercussions for communities that rely on these sectors. For fishers, ALDFG poses serious safety risks, as entanglement and navigational hazards can jeopardize vessels and crews.

Table 7: Economic and social costs of ALDFG (After Mac Fayden et al., 2009)

Direct costs	Lost gear/ vessels because of entanglement/ costs of replacement Emergency rescue Time and fuel searching for and recovering vessels, reduced time of fishing Costs of retrieval programs/ activity of removal, management measures Costs of gear marking, monitoring to reduce ALDFG
Indirect costs	Reduced Income/ Added value from ghost fishing Reduced multiplier effects from reduced fishing income Costs of research into reducing ALDFG Decreased buying because of concerns about ghost fishing / ALDFG
Social costs	Reduced employment in fishing communities Reduced recreational, tourism and diving benefits
	Safety risks for fishers and vessels/ decreased manoeuvrability, navigation hazards

The global economic costs of ALDFG are challenging to quantify, but regional studies offer insight into its magnitude. In major crustacean fisheries, removing less than 10 percent of derelict pots could yield an annual recovery of USD 831 million in landings (Scheld et al., 2016). This figure underscores the potential scale of economic losses associated with ALDFG globally. However, recovery costs can sometimes exceed the financial benefits, as seen in certain fisheries. Balancing the economic costs of gear recovery with its ecological and economic benefits requires careful analysis and strategic planning. In Europe (UNEP MAP, 2015a).

Recognizing the growing challenges posed by ALDFG, there is an increasing emphasis on evidence-based management and mitigation strategies. Research highlighted in the Marine Policy special issue on ALDFG emphasizes the need for improved monitoring systems, a better understanding of the drivers and causes of gear loss, and effective policies to address its production and impacts (Gilman et al., 2023). Such efforts are essential to safeguard marine ecosystems, support sustainable fisheries, and reduce the economic and social costs associated with lost and discarded fishing gear.

5 MANAGEMENT OF WASTE FROM FISHING VESSELS

The management of waste generated by the fishing industry has become a critical environmental and economic issue globally, particularly in addressing the problem of ALDFG. These materials, often made from durable synthetic plastics, persist in marine environments for decades, posing risks to biodiversity, maritime activities, and coastal livelihoods. ALDFG not only impacts marine ecosystems but also imposes financial burdens on fishers due to gear replacement costs and lost catch. Coastal tourism and recreational activities suffer as litter from fishing vessels may accumulate along shorelines, further amplifying the socio-economic toll. In response, international organizations, regional bodies, and local governments have initiated a range of measures to address ALDFG and other waste streams from fishing vessels. These include prevention strategies, recovery programs, port waste management systems, and recycling initiatives (**Figure 9**).

Innovative projects worldwide are exploring sustainable practices and fostering collaboration among stakeholders to mitigate the environmental and economic impacts of fishing-related waste.

The present chapter provides a comprehensive overview of waste management practices in the fishing industry, focusing on the Mediterranean and global initiatives. It explores prevention measures, operational strategies, gear marking and recovery systems, waste management infrastructure in ports, and recycling techniques. Additionally, it examines ongoing projects and international legal frameworks governing marine litter, concluding with recommendations for integrated solutions to address ALDFG and promote sustainable fisheries management.

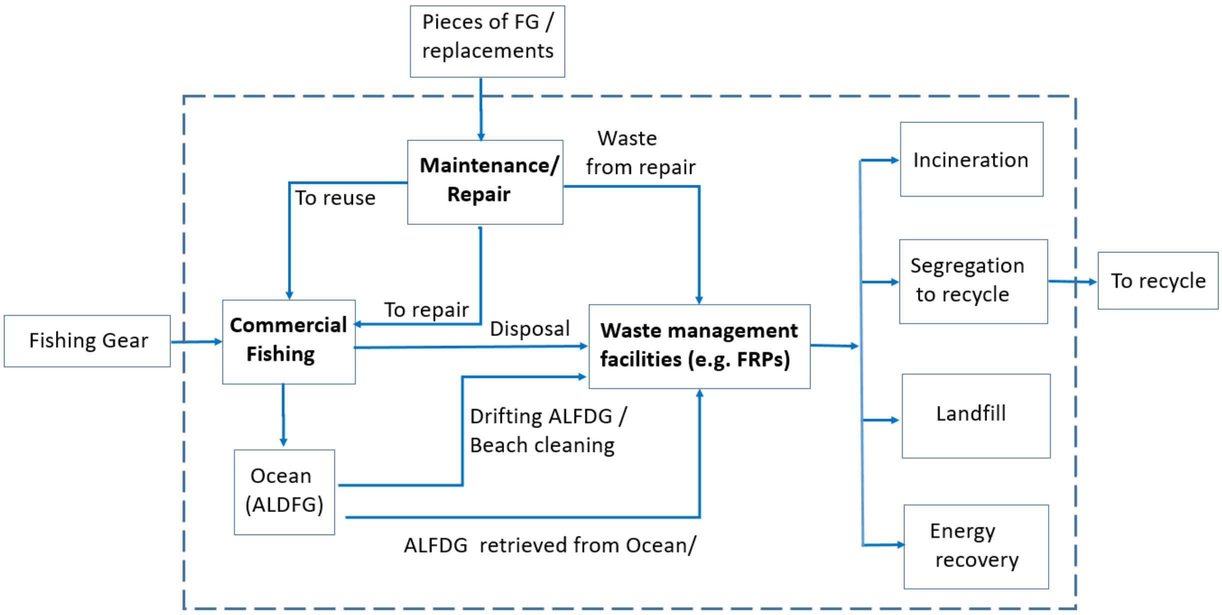

Figure 9: The life cycle of a fishing gear (Modified from Deshpande et al., 2020)

5.1 Prevention measures

Preventing ALDFG requires a combination of regulatory, educational, and technological approaches, supported by collaboration among governments, fishing communities, and industry stakeholders. Prevention strategies aim to address the root causes of gear loss by improving operational practices, fostering awareness, and promoting technological and regulatory measures that minimize risks during fishing activities. By prioritizing prevention, stakeholders can reduce environmental harm, lower the costs associated with gear replacement, and enhance the sustainability of fisheries.

One of the most effective prevention strategies involves improving the design and durability of fishing gear (Juan et al., 2021, Cerbule et al., 2023, De Domenico, 2023, Moreno et al., 2023). Gear constructed with robust materials and equipped with anti-fouling treatments is less likely to break or degrade under normal use, thereby reducing the chances of accidental loss. Furthermore, incorporating biodegradable materials into gear design ensures that, even if lost, the environmental impact is minimized. These materials degrade naturally over time, avoiding long-term contributions to marine litter and mitigating the threat of ghost fishing (Loizidou et al., 2024). Pilot projects around the world have demonstrated the feasibility of biodegradable gear, but further research and cost reductions are necessary to encourage widespread adoption, noting possible environmental impacts of new materials (Karadurmuş and Bilgili 2024).

Enhanced fisheries management is another critical prevention measure. Strategies such as spatial planning and zoning help prevent gear conflicts, one of the leading causes of gear abandonment and loss (Macfadyen et al., 2009). For instance, demarcating exclusive zones for specific fishing activities reduces entanglements between trawl nets and fixed gear like gillnets or traps. Additionally, regulations limiting the number of active fishing vessels or setting seasonal fishing quotas can reduce the intensity of fishing activity in vulnerable areas, lowering the risk of gear loss due to overcrowding.

Raising awareness and providing training for fishers are also key components of prevention efforts (Mengo et al., 2023). Education programs can highlight the economic and ecological costs of ALDFG, fostering a sense of responsibility and stewardship among fishing communities. These programs often include training on best practices for gear handling, maintenance, and disposal, ensuring that fishers are equipped with the knowledge to minimize waste. Awareness campaigns tailored to local contexts, such as those focusing on artisanal and small-scale fisheries, are particularly effective in regions where regulatory oversight is limited.

Policy interventions at national and international levels further support prevention (Gilman, 2015; FAO, 2021 &. 2024b, Giskes et al., 2022). For example, mandating gear marking and traceability improves accountability, discouraging illegal disposal and incentivizing proper retrieval of lost gear. The FAO Voluntary Guidelines on the Marking of Fishing Gear (FAO, 2019c) provide a global framework for implementing such measures. At the regional level, Recommendation GFCM/42/2018/11 on the regional marking of fishing gear establishes a harmonized approach for gear identification in the Mediterranean and Black Sea, supporting monitoring and compliance.

In addition, Resolution GFCM/44/2021/14 on abandoned, lost or otherwise discarded fishing gear encourages the development of national action plans and promotes preventive and mitigation measures, including marking, reporting, and retrieval systems. These instruments collectively strengthen the regional governance framework for addressing ALDFG. Moreover, financial incentives, such as subsidies for gear repairs or access to affordable port waste facilities, reduce the economic barriers that often lead to gear abandonment. In some regions, extended producer responsibility (EPR) schemes require manufacturers to fund or manage the collection and recycling of end-of-life gear, creating economic incentives to design more sustainable products.

Lastly, technological innovations offer new avenues for prevention. Advanced navigation systems, such as GPS trackers and sonar devices, help fishers avoid obstacles and high-risk areas where gear loss is likely. Digital tools, including mobile apps for reporting lost gear, facilitate rapid response and recovery efforts. Integrating these technologies into fishing operations has the potential to drastically reduce the frequency of ALDFG.

5.2 Strategies for Fishing Operations that Limit ALDFG

Effective fishing operations can significantly reduce the likelihood of ALDFG. Operational strategies focus on minimizing the risks of accidental gear loss, mitigating the factors that contribute to gear abandonment, and fostering collaboration among fishers to reduce conflicts. By improving fishing practices and fostering responsible behaviour, these strategies help protect marine ecosystems while supporting the economic sustainability of fisheries (GESAMP, 2021, Andreassen, 2024).

One of the primary approaches to reducing ALDFG is the adoption of better gear deployment and retrieval practices. Properly deploying fishing gear, with attention to weather conditions, water currents, and seabed topography, can prevent gear from becoming snagged or lost (Richardson et al., 2019). Fishers are encouraged to use precise navigation tools to identify safe locations for deploying nets, traps, and lines, avoiding areas with high risks of entanglement, such as coral reefs or underwater obstructions (Richardson et al., 2019). Similarly, efficient retrieval practices, including the use of retrieval aids like grapnels and lifting equipment, minimize the chances of leaving gear behind.

Collaborative efforts among fishers are vital in reducing ALDFG. Conflict over fishing grounds is a common cause of gear loss, particularly in areas with overlapping fishing activities (FAO, 2016). By coordinating fishing schedules and zones through local associations or regional management bodies, fishers can avoid gear conflicts—such as trawl nets colliding with fixed gear or whn high concentrations of fishing activity increase the likelihood of loss. Fisheries cooperatives often play a key role in facilitating these collaborations, ensuring that all parties adhere to agreed-upon guidelines.

Seasonal closures and spatial zoning further support sustainable fishing operations by reducing the intensity of fishing activities in high-risk areas. Temporal management measures, such as rotating fishing grounds or implementing seasonal restrictions, reduce the cumulative impact of gear deployment in sensitive habitats. Additionally, spatial zoning that allocates specific areas for different types of fishing gear prevents conflicts between fleets using incompatible methods, such as trawling and longlining (Richardson et al., 2018).

Training programs for fishers are an essential component of operational strategies to limit ALDFG. These programs emphasize the importance of maintaining gear including regular inspections and repairs, to prevent accidental loss. Proper maintenance reduces the likelihood of gear failure during use, while training on how to handle unexpected challenges, such as snagging or gear entanglement, equips fishers with practical solutions to avoid abandonment. Workshops and on-site demonstrations have proven particularly effective in small-scale and artisanal fishing communities, where access to formal training is often limited.

Data collection and information-sharing systems also play a crucial role in reducing ALDFG. By maintaining records of lost gear, fishing associations and management bodies can identify patterns and high-risk zones where preventive measures are needed (Gesamp, 2021). Real-time data sharing among fleets allows fishers to avoid areas where gear has been recently lost, reducing the chances of secondary losses or ghost fishing. Digital platforms, including mobile applications for reporting and tracking lost gear, enhance the efficiency of these systems and promote accountability.

While their implementation is a long-term process, the integration of sustainable fishing practices into existing regulatory frameworks ensures that operational strategies are widely adopted (Andreassen, 2024). For example, fisheries management plans can include mandatory reporting of lost gear, with penalties for non-compliance. Regulations requiring the use of gear designed to reduce loss, such as nets with reinforced seams or traps equipped with degradable panels, further support operational improvements.

These measures are aligned with Resolution GFCM/44/2021/14 on abandoned, lost or otherwise discarded fishing gear, which prohibits the abandonment and discarding of fishing gear (except in cases of force majeure), and requires vessels of 20 metres length overall (LOA) and above to carry equipment for retrieving lost gear and to make every reasonable attempt to recover it. If retrieval is not possible, the resolution mandates that the master of the vessel notify the flag CPC within 24 hours, providing details such as the vessel name, gear type and quantity, time and location of loss, and actions taken to retrieve it. The flag CPC must then inform the coastal CPC and notify the GFCM Secretariat without delay. This resolution reinforces the importance of operational responsibility, transparency, and regional cooperation in addressing ALDFG. Effective, enforcement of these measures is critical and requires active monitoring and collaboration among regulatory authorities and local communities.

Finally, technology plays an increasingly important role in limiting ALDFG during fishing operations. The use of GPS trackers, acoustic buoys, and remote sensing technologies allows fishers to monitor the location of their gear in real-time, reducing the risk of loss. Advances in sonar technology enable fishers to identify obstacles and entanglement hazards before deploying gear, enhancing safety and efficiency. Integrating these technologies into routine fishing operations not only reduces ALDFG but also improves overall productivity.

5.3 Localization and Marking of Fishing Gear

Localization and marking of fishing gear are vital strategies for preventing and managing ALDFG (Prędki et al., 2019; Basurko et al., 2023). These practices enhance traceability, accountability, and retrieval efficiency, providing a proactive approach to reducing the environmental and economic impacts of gear loss. By implementing gear marking systems and technologies for real-time localization, fisheries can minimize ghost fishing, protect marine ecosystems, and foster sustainable practices.

Marking fishing gear involves the use of identifiable tags, labels, or markers that link the gear to its owner or operator. This system facilitates accountability by enabling authorities to trace gear found at sea or washed ashore. In the GFCM area of application, including the Mediterranean, Recommendation GFCM/42/2018/11 on the regional marking of fishing gear provides a framework for the identification of passive fishing gear, particularly for vessels over 15 metres in length authorized to target species managed by the GFCM. This recommendation encourages the use of marking systems that allow gear to be readily identified, in accordance with national legislation and internationally accepted standards, such as the FAO Voluntary Guidelines on the Marking of Fishing Gear (FAO, 2019). Marking systems typically incorporate unique identifiers, such as vessel registration numbers, to facilitate monitoring, control and surveillance (MCS) and to deter intentional abandonment.

Technological advancements have significantly enhanced the potential for gear localization and marking. Radio-Frequency Identification (RFID) tags and GPS-enabled buoys allow for real-time tracking of fishing gear. RFID tags are particularly effective for nets and traps, as they provide a durable and cost-effective means of identification (Grabia et al., 2019). When coupled with digital tracking systems, fishers can monitor their gear's location throughout the fishing process, reducing the risk of accidental loss. GPS-enabled buoys, often equipped with solar power and communication technologies, transmit precise location data to fishers, ensuring swift recovery in case of drifting or entanglement.

Acoustic devices are also gaining prominence in gear localization (Matthias et al., 2023). These devices emit sound signals that can be detected by fishers using specialized receivers. Acoustic tracking is particularly useful in deep-sea or high-turbidity environments where traditional visual markers are less effective. This technology has been successfully deployed in lobster and crab fisheries, where submerged traps often remain unattended for extended periods.

Mandatory gear marking regulations have been adopted in many regions, requiring fishers to label their equipment according to standardized guidelines. These regulations are often enforced alongside broader fisheries management plans, ensuring alignment with sustainability goals (Andreassen, 2024). For instance, Regional Fisheries Management Organizations (RFMOs) such as the Western and Central Pacific Fisheries Commission (WCPFC) mandate gear marking to prevent illegal, unreported, and unregulated (IUU) fishing, which often contributes to ALDFG. By integrating gear marking into licensing and reporting systems, authorities can enhance monitoring and compliance. In the Mediterranean and Black Sea, the GFCM encourages the exchange of experiences among countries and supports capacity-building efforts, particularly for developing CPCs, to facilitate the implementation of gear marking measures.

Localization technologies not only aid in gear recovery but also support conflict resolution among fishers. In areas with overlapping fishing activities, tracking systems help avoid disputes by delineating gear locations and preventing unintentional interference. Challenges remain in implementing localization and marking systems, particularly for small-scale and artisanal fisheries. These sectors often face financial and technical barriers to adopting advanced tracking technologies. To address this, governments and non-governmental organizations (NGOs) have initiated capacity-building programs and subsidies to support gear marking and localization (Stolte, 2019). Pilot projects in developing regions have demonstrated the feasibility of low-cost solutions, such as biodegradable tags and community-based monitoring systems.

5.4 Recovery of ALDFG at Sea and Pre-Treatment of Collected Gear

The recovery of ALDFG at sea is a crucial step in mitigating its environmental and economic impacts. Retrieval efforts help reduce ghost fishing, protect marine habitats, and remove hazardous debris from navigational routes. Complementing these efforts, pre-treatment processes ensure that collected gear is prepared for recycling or disposal, minimizing waste and supporting sustainable waste management systems. Recognizing fishers as both stakeholders and victims of marine litter is essential. Their involvement in mitigation solutions can be highly effective when supported by appropriate regulatory, financial, and technical frameworks. A more nuanced understanding of the sector's dual role—as both a potential source and a key partner in addressing marine litter—can help foster greater collaboration, reduce tensions, and build trust between authorities and fishing communities.

In the Mediterranean, in line with Resolution GFCM/44/2021/14, specific provisions apply to the retrieval of lost gear by vessels of 20 metres length overall (LOA) and above, including the obligation to carry retrieval equipment and report unrecovered gear. These measures support broader efforts to reduce the risks associated with ALDFG in the GFCM area of application.

Recovery operations often involve targeted initiatives such as Fishing for Litter (FFL) programs, where fishers voluntarily collect marine litter, including ALDFG, during their regular fishing activities (Mengo et al., 2017). These programs, implemented in regions like the North Sea and the Mediterranean, engage fishing communities in marine conservation while raising awareness about the impacts of marine litter. Participating vessels are equipped with storage facilities for collected debris, which is then offloaded at designated ports for processing. These initiatives not only contribute to environmental clean-ups but also foster a sense of responsibility among fishers.

In addition to voluntary efforts, government-led recovery programs deploy specialized vessels and equipment to retrieve ALDFG from high-risk areas, such as marine protected zones and heavily fished regions. Advanced technologies, including remotely operated vehicles (ROVs) and side-scan sonar, are employed to locate and recover submerged gear (Matthias et al., 2023). These tools are particularly effective for deep-sea operations, where manual retrieval is impractical. For instance, ROVs can detect and lift nets and traps from coral reefs and other sensitive habitats, preventing further ecological damage.

Once ALDFG is recovered, pre-treatment processes are essential to prepare the material for recycling or proper disposal (Bazurko et al., 2023). Pre-treatment begins with sorting the collected gear by material type, separating plastics, metals, and organic debris. Manual sorting is often required to identify recyclable components and remove contaminants such as sand, algae, and bio-fouling organisms. This step is critical for ensuring the quality of recycled materials and reducing processing costs (Stolte et al., 2019).

Cleaning is another vital aspect of pre-treatment (Press, 2019). High-pressure water jets and mechanical scrubbers are commonly used to remove organic and inorganic residues from recovered gear. Composting methods may also be employed for biological degradation of organic matter, particularly for heavily fouled gear. Cleaned materials are then shredded or cut into smaller pieces to facilitate transportation and further processing. For example, nets may be reduced to manageable lengths, and rigid plastics may be ground into flakes or pellets for recycling. Innovative technologies are increasingly being integrated into pre-treatment processes. For instance, automated sorting systems, Chemical pre-treatment methods, enhance the efficiency and scalability of pre-treatment processes, making recycling a more viable. Challenges in recovery and pre-treatment include logistical difficulties, high operational costs, and limited recycling infrastructure in many regions. (IMO /FAO, 2023). Moreover, the variability in material composition and the presence of contaminants complicate pre-treatment processes, reducing the economic feasibility of recycling.

5.5 Waste Management in Harbours and Port Reception Facilities

Fishing ports serve as central points for the collection, processing, and disposal of waste, including ALDFG (**Figure 10**). By providing accessible and well-equipped facilities, harbours can reduce the improper disposal of fishing gear and operational waste at sea, thus mitigating the environmental and economic impacts of marine litter.

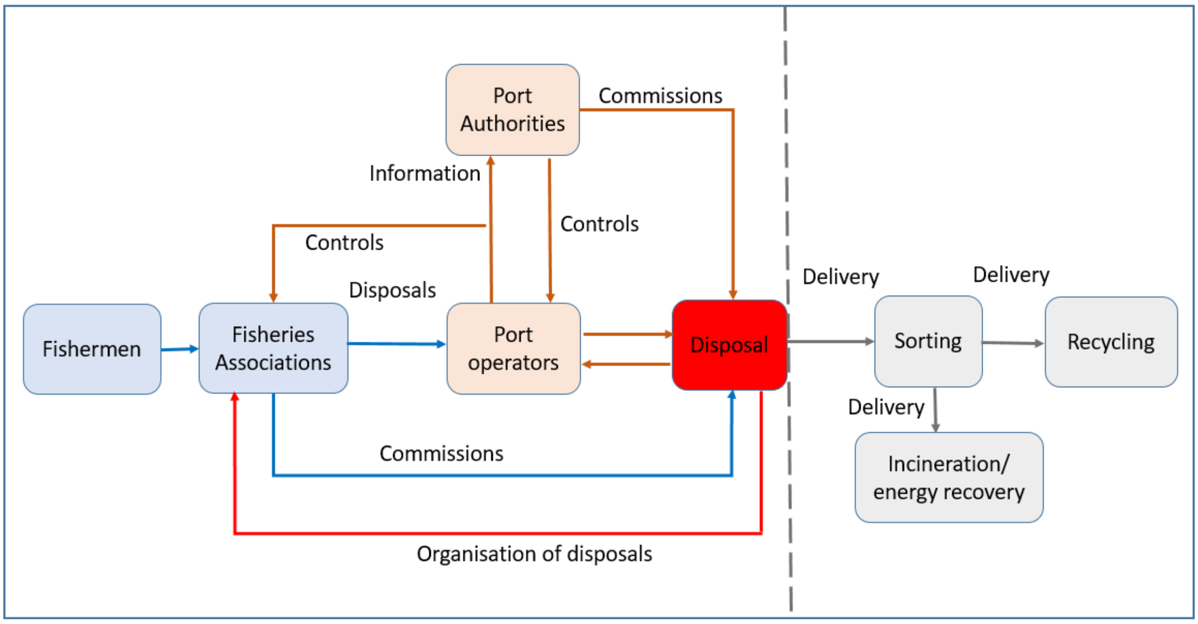

Figure 10. Identification of stakeholders along the ALDFG waste management pathway (after IMO/FAO 2023a)

PRFs are mandated under international agreements, such as MARPOL Annex V, which requires ports to have adequate facilities for receiving waste from vessels. These facilities must be capable of handling a variety of waste streams, including plastics, oils, and hazardous materials, as well as specialized categories like end-of-life fishing gear. For fishing ports, this means tailoring infrastructure and services to accommodate the unique waste management needs of fishing fleets (IMO/ FAO, 2023b). Dedicated storage areas for ALDFG, bins for segregating recyclables, and collection systems for marine litter retrieved during Fishing for Litter (FFL) initiatives are all essential components of an effective PRF.

Accessibility is a key factor in the success of port waste management systems, and ports must ensure that waste reception facilities are available during peak landing times and that the process of offloading waste is streamlined to avoid delays. Incentives, such as reduced fees for waste disposal or compensation for participating in gear retrieval programs, can further encourage compliance and reduce instances of illegal dumping.

Cost recovery systems play an important role in the financial sustainability of PRFs (IMO/ FAO, 2023c). The "indirect fee" model is widely regarded as an effective approach, wherein vessels pay a standard fee for waste management services regardless of whether they deliver waste. However, this model may not always be adapted for ALDFG, which is not consistently delivered in all ports. For fishing ports, the inclusion of ALDFG in the fee structure is particularly important, as it encourages fishers to return damaged or obsolete gear to port rather than discarding it at sea.

Port authorities, local governments, fishing associations, and environmental organizations must work together to design, implement, and monitor waste management plans. For example, partnerships with recyclers can ensure that collected materials are processed sustainably, while educational campaigns can raise awareness among fishers about the environmental impacts of marine litter and the benefits of proper waste disposal.

Despite these efforts, challenges remain in implementing effective waste management systems in harbours, particularly in smaller ports with limited resources (GESAMP, 2021; IMO/ FAO, 2023 b & c). Inadequate infrastructure, lack of financial support, and insufficient regulatory enforcement often result in suboptimal waste management practices. To address these issues, targeted investments are needed to upgrade port facilities and expand the capacity of PRFs. International funding mechanisms, such as grants from environmental agencies or development banks, can play a crucial role in supporting these initiatives.

Regional harmonization of waste management practices is another critical factor. Standardizing procedures for waste collection, segregation, and reporting across ports ensures consistency and facilitates cooperation among neighbouring regions. In the European Union, the Port Reception Facilities Directive provides a framework for harmonizing waste management standards, promoting best practices, and integrating marine litter reduction efforts into broader environmental policies.

Finally, technological advancements (electronic waste tracking systems, mobile applications) for reporting and scheduling waste deliveries, offer opportunities to improve waste management in harbours, also enhancing transparency and efficiency.

5.6 Recycling and other options

Recycling is a pivotal component in the management of ALDFG and other waste from fishing activities (Solte et al., 2019; Press, 2019). By converting discarded materials into reusable resources, recycling reduces the environmental impact of marine litter, supports the circular economy, and provides economic opportunities in coastal communities (Figure 11). Innovations in recycling technology and expanded infrastructure are driving progress in transforming fishing gear waste into valuable products (Charter & Carruthers, 2022), but challenges remain in scaling these efforts globally.

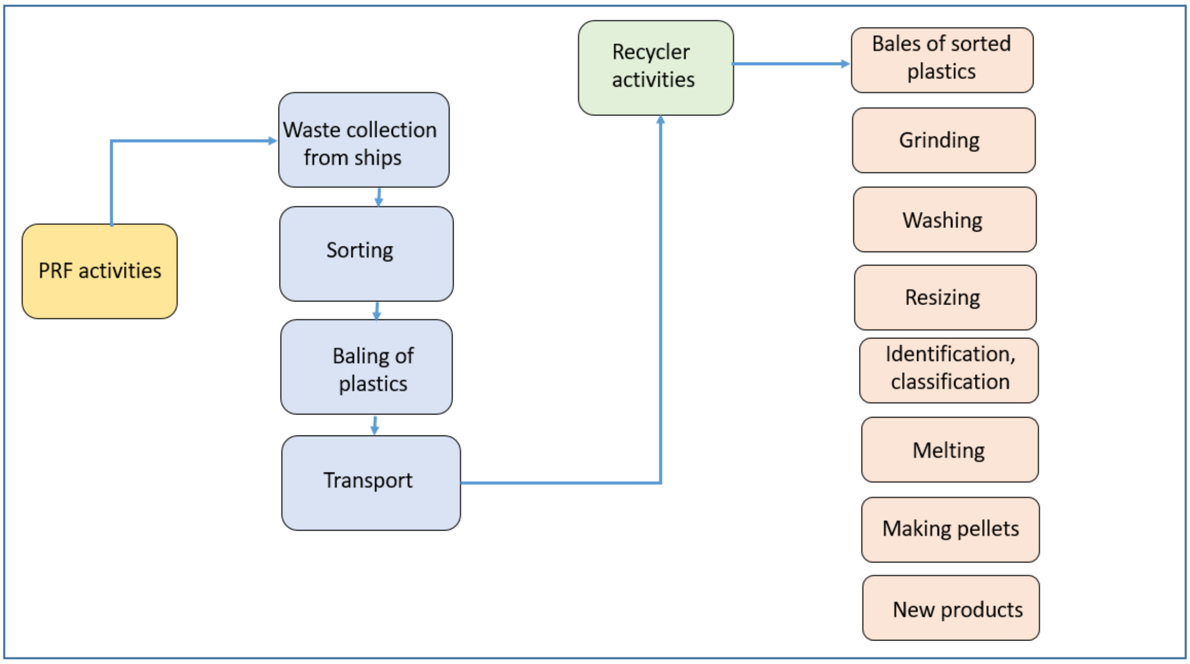

Figure 11. Steps at Port reception and recycling facilities (After IMO/FAO, 2023a)

Fishing gear is predominantly made from durable synthetic materials such as nylon, polypropylene, and high-density polyethylene (HDPE). These plastics are designed to withstand harsh marine environments, making them ideal for fishing but challenging to recycle (Juan et al., 2021). Over time, gear exposed to ultraviolet light, saltwater, and mechanical stress can degrade, complicating its processing into high-quality recyclates. Despite these challenges, mechanical and chemical recycling techniques are enabling the conversion of fishing gear into a range of products.

Mechanical recycling involves shredding, melting, and reforming materials into new products. This method is commonly used for nets, ropes, and lines made from homogeneous polymers like nylon or HDPE with some companies that have started industrial-scale recycling of fishing gear (Stolte, 2019; Deshpande et al., 2020; Su et al., 2023), . Discarded nylon nets are most often repurposed into fibres for clothing or carpet production, while HDPE ropes are transformed into durable containers or furniture.

Chemical recycling is gaining attention as an alternative for processing degraded or mixed-material fishing gear. This method breaks down polymers into their chemical building blocks, which can then be purified and repolymerized into new plastics. The Econyl® process, developed by Aquafil, is a leading example of chemical recycling in action. It converts nylon fishing nets and other post-consumer waste into high-performance materials used in fashion and interior design. By recovering raw materials rather than relying on virgin inputs, chemical recycling reduces both plastic pollution and greenhouse gas emissions.

Recycling initiatives also focus on creating consumer goods and artisanal products from fishing gear waste. Small businesses and NGOs have been instrumental in this effort, crafting accessories, homeware, and recreational items from discarded nets and ropes. For instance, “Bracenet” in Germany produces bracelets and bags from recovered ghost nets, while “Bureo” in Chile repurposes nets into skateboards and sunglasses. These initiatives not only raise awareness about marine litter but also provide economic opportunities for local communities.

Collaborations between fishing communities, industry stakeholders, and recyclers are key to scaling recycling efforts. Programs like Healthy Seas partner with fishers to collect end-of-life gear and deliver it to processing facilities, integrating waste recovery into the recycling supply chain. These partnerships often include incentives for fishers to return used gear to port rather than discarding it at sea, reducing the prevalence of ALDFG and ensuring a consistent feedstock for recyclers.

Despite its promise, recycling fishing gear faces several challenges. Contamination with organic matter, sand, and other debris complicates pre-treatment processes, increasing costs and reducing material quality. Additionally, the diversity of gear materials—often composed of multiple polymers or reinforced with metal components—requires advanced sorting and separation technologies. In regions with limited recycling infrastructure, these challenges are exacerbated, leading to reliance on landfilling or incineration. The GFCM Catalogue of Fishing Gear provides a valuable reference for understanding the structure and material composition of gear types used in the region, supporting the design of effective recycling and pre-treatment processes (FAO, 2023c).

Innovative approaches are being developed to address these issues. Automated sorting systems equipped with optical and sensor-based technologies improve the efficiency and precision of material separation. Pre-treatment methods, such as chemical washing and shredding, enhance the quality of recyclates by removing contaminants. Investment in regional recycling hubs equipped with these technologies can help overcome logistical barriers, particularly in remote or under-resourced areas.

Economic considerations also play a significant role in the viability of recycling. The costs of collecting, transporting, and processing fishing gear often exceed the market value of recycled materials, creating financial disincentives for stakeholders. Extended Producer Responsibility (EPR) schemes offer a potential solution by requiring manufacturers to fund the end-of-life management of their products. Subsidies, tax incentives, and certification programs for recycled products can further support the economic sustainability of recycling initiatives.

Recycling fishing gear contributes to environmental conservation by reducing the volume of waste entering marine ecosystems and lowering the demand for virgin plastics. It also supports economic development by creating jobs in waste collection, processing, and manufacturing. By integrating recycling into the management of fishing gear, stakeholders can achieve both environmental and economic benefits, advancing the goals of sustainability and circular economy principles.

Policy frameworks at the national and international levels are essential for promoting recycling as part of broader waste management strategies. Regulations mandating the segregation and return of end-of-life fishing gear to port reception facilities encourage proper disposal and facilitate recycling. International initiatives, such as the GloLitter Partnerships Project, emphasize capacity building and knowledge sharing to enhance recycling infrastructure and practices globally. Recently, initiatives to revise Fisheries Standard to require assessments and management of their impact on marine habitats and bycatch (McLennan et al., 2023). These updates, developed through extensive research, public consultation, and policy testing, aim to prevent gear loss and minimize environmental damage through best practice management strategies, including ecolabelling and certification programs, and leverage market-based incentives to improve fishery sustainability

Other options and scenarios covering processes from retrieval to pre-treatment, transport, and final treatment of ALDFG have been analysed through a Life Cycle Assessment (LCA) comparing mechanical recycling, syngas production, energy recovery, and landfill disposal (Schneider et al., 2023). Typically, Mechanical recycling was especially effective in reducing waste-related emissions, while energy recovery via incineration provides a feasible alternative. Syngas Production and Landfill Disposal options were less environmentally viable. Syngas production demands high electricity inputs, and landfill disposal poses risks of long-term damage, particularly through hazardous material leakage. The study also calls for integrating economic and social considerations into future evaluations and stresses the need for preventive measures to mitigate marine litter at its source.

6 PORT RECEPTION FACILITIES IN THE MEDITERRANEAN SEA

Port reception facilities (PRFs) are integral to the maritime framework, particularly in regions like the Mediterranean Sea, which faces significant environmental pressures due to its enclosed nature, high levels of shipping traffic, and intense fishing in some well-defined areas. These facilities are vital for ensuring the safe and efficient handling of ship-generated waste, especially fishing vessels, reducing pollution risks, and protecting marine ecosystems. The governance of PRFs is anchored in international law, with the MARPOL Convention serving as the cornerstone. Adopted in 1973, revised in 2018, MARPOL sets global standards for preventing marine pollution from ships, addressing pollutants through its six annexes. Each annex specifies measures to minimize the environmental impact of maritime operations, including the provision of PRFs at ports.

The Mediterranean's designation as a Special Area under MARPOL Annexes I (oil) and V (garbage) further underscores its ecological sensitivity and the heightened responsibilities of coastal states. This designation imposes stricter discharge standards, ensuring that waste generated by ships is appropriately managed onshore rather than being discharged into the sea.

The Mediterranean's unique geographic and economic characteristics intensify the importance of PRFs in the region. Its coastline spans 22 countries, with a diverse array of ports ranging from major commercial hubs to smaller, resource-constrained facilities in North Africa and the Eastern Mediterranean. The region accommodates approximately 30% of global maritime traffic, a high level of activity generating significant volumes of waste, including operational residues, garbage, sewage, and discarded fishing gear, placing immense pressure on PRFs.

Regional regulatory frameworks, such as the Barcelona Convention's Regional Plan for Marine Litter Management, complement MARPOL by providing tailored guidelines for Mediterranean states. This plan emphasizes harmonizing PRF practices, fostering collaboration among stakeholders, and encouraging innovative waste management approaches. For instance, the Regional Plan promotes the adoption of no-special-fee (NSF) systems to incentivize waste disposal at ports, reducing the likelihood of illegal discharges. By aligning regional initiatives with MARPOL standards, the plan enhances the effectiveness of PRFs while addressing the Mediterranean's specific environmental and operational challenges.

The European Union (EU) also plays a pivotal role in shaping PRF practices in the Mediterranean. Directive 2000/59/EC, which governs PRFs across EU member states, introduces measures that go beyond MARPOL requirements. It mandates pre-arrival waste notifications, ensuring that ports can adequately prepare for waste reception. This is particularly relevant in the Mediterranean, where the diversity of ports necessitates tailored approaches to waste management. The directive also emphasizes cost recovery, implementing the "polluter pays" principle to ensure that the financial burden of PRFs is equitably distributed. In large Mediterranean ports, this principle has facilitated the development of advanced PRFs equipped to handle a wide range of waste types.

Despite these robust frameworks, the Mediterranean faces persistent challenges in PRF implementation. Resource disparities between northern and southern Mediterranean ports are a significant issue. While ports in countries like France, Italy, and Spain often boast state-of-the-art facilities, those in North Africa and parts of the Eastern Mediterranean frequently lack the infrastructure and technical expertise required to meet MARPOL standards. This imbalance hinders the region's ability to uniformly address ship-generated waste and underscores the need for targeted investments in under-resourced areas.

The types of waste handled by PRFs in the Mediterranean reflect the region's diverse maritime activities. Operational waste, such as oily residues, sewage, and garbage, constitutes a significant portion of the waste stream. Each type presents unique challenges, requiring specialized treatment and adhesion strict health and environmental regulations. The Mediterranean also grapples with significant volumes of marine litter, particularly discarded fishing gear and plastics that necessitate effective segregation and recycling to minimize environmental impact. These pollutants not only harm marine life but also threaten the region's vital fishing and tourism industries.

Financial sustainability is a constraint for effective PRF operations, and the Mediterranean has seen varied approaches to cost recovery. The three primary models—NSF systems, administrative fee systems, and direct fee systems—are all employed in the region. NSF systems (No-Special-Fee systems), widely adopted in Northern Mediterranean ports, charge a flat fee regardless of the waste volume deposited, making them particularly effective in reducing illegal dumping. Ports like Marseille and Barcelona have successfully implemented NSF systems, integrating them with broader waste management strategies. Administrative fee systems, which combine fixed charges with variable fees based on waste quantities, are less common but provide a balanced approach that rewards efficient waste management practices. Direct fee systems, while transparent, are rarely used in the Mediterranean due to their potential to discourage PRF use (MAP/REMPEC, 2019).

Regional initiatives have sought to address these financial and operational challenges. The Marine Litter-MED Project, funded by the EU, has been instrumental in improving PRFs across the Mediterranean. By providing technical support and fostering capacity building, the project has enabled ports in countries like Tunisia and Türkiye to upgrade their facilities and adopt best practices. These efforts have been complemented by collaborations with international organizations such as REMPEC (MAP/REMPEC, 2019), which has facilitated knowledge exchange and technical assistance among Mediterranean states.

Global best practices offer additional insights for enhancing PRFs in the Mediterranean. The Port of Antwerp in Belgium exemplifies the benefits of NSF systems, combining flat fees with advanced waste processing technologies to incentivize compliance. In Sweden, the Port of Stockholm highlights the value of pre-arrival waste notifications, particularly for passenger vessels, which are a significant source of waste in Mediterranean ports like Dubrovnik and Venice. Fishing ports like Peterhead in Scotland demonstrate the importance of facilities designed specifically for marine litter, including discarded fishing nets—a critical issue in the Mediterranean's fishing-intensive regions (MAP/REMPEC, 2019).

Monitoring and performance metrics are essential for evaluating the effectiveness of PRFs in the Mediterranean. Key indicators include waste volumes received, facility utilization rates, and compliance levels among ships. However, disparities in reporting practices across the region complicate data collection and analysis. Harmonizing reporting standards and leveraging digital tools can enhance transparency and accountability, enabling ports to identify gaps and prioritize interventions. For instance, a unified reporting system could help Mediterranean ports track the impact of NSF systems on waste deposition patterns, informing policy adjustments and resource allocation. Alternatively, a unified reporting system dedicated to fishing Harbours, and waste from fishing court favour monitoring a reporting in a harmonized manner.

To strengthen PRFs in the Mediterranean, several recommendations emerge. First, enhancing coordination among Mediterranean states is crucial. Regional bodies like the Union for the Mediterranean and international organizations such as the IMO must align their efforts to ensure regulatory coherence and effective implementation. Second, sustained investment in infrastructure is essential to address resource disparities. Public-private partnerships can mobilize funding for under-resourced ports, enabling them to upgrade facilities and adopt advanced technologies. Third, expanding the adoption of NSF systems can reduce illegal dumping while ensuring financial sustainability. Finally, education and training programs tailored to Mediterranean stakeholders can raise awareness about waste management regulations and best practices, fostering a culture of compliance. In The Mediterranean Sea, the NSF system is emphasized for fishing ports to ensure waste disposal is economical and accessible for small-scale fishers (UNEP MAP, 2024). In this context, the General Fisheries Commission for the Mediterranean (GFCM) also contributes by promoting responsible fishing practices and supporting efforts to reduce gear loss and improve gear return to port, particularly through its recommendations and capacity-building initiatives.

In conclusion, the Mediterranean Sea exemplifies both the challenges and opportunities associated with PRF management. For fishing activity, its unique characteristics—diversity of fishing practices, efforts, and fishing harbours infrastructure—make it a critical focus for global efforts to reduce marine pollution. While significant progress has been made in aligning Mediterranean PRFs with international and regional standards, continued investment, innovation, and collaboration are necessary to address persistent gaps. By addressing Small Scale Fisheries, adopting best practices and fostering regional cooperation, the Mediterranean could promote a model for sustainable fishing operations and marine conservation.

7 GLOBAL INITIATIVES

7.1 Initiatives on ALDFGs

A wide range of initiatives addressing ALDFG and other forms of fishing-related waste have been implemented worldwide. These initiatives involve governments, international organizations, non-governmental organizations (NGOs), and private sector stakeholders. These initiatives operate across regions and target multiple aspects of the problem, including prevention, recovery, recycling, and raising awareness, showcasing the global effort to mitigate the environmental and socioeconomic impacts of marine litter.

At the multilateral level, international agreements such as the **MARPOL Convention** and the **London Convention and Protocol** provide the regulatory framework for managing waste from fishing vessels. MARPOL Annex V prohibits the discharge of plastics at sea and mandates the establishment of PRFs for proper waste disposal. The London Convention and Protocol reinforce these measures by emphasizing the prevention of harmful waste dumping and promoting the safe management of ship-generated waste. These agreements have been instrumental in setting global standards for waste management in the maritime sector.

The **GloLitter Partnerships Project**, led by the International Maritime Organization (IMO) and the Food and Agriculture Organization (FAO), is a flagship initiative aimed at reducing sea-based marine plastic litter. GloLitter supports developing countries in creating national action plans, improving port reception facilities, and integrating waste management practices into regulatory frameworks. The project emphasizes capacity building and technical assistance, helping nations implement solutions such as gear marking systems, waste segregation protocols, and public awareness campaigns. By facilitating global knowledge exchange, GloLitter promotes scalable and replicable approaches to addressing ALDFG.

The **Fishing for Litter (FFL)** program is another widely implemented initiative that engages fishers in the retrieval of marine litter. Active in regions such as the North Sea, Baltic Sea, and Mediterranean, FFL provides vessels with bags for collecting litter encountered during fishing operations. Once returned to port, the collected waste is sorted and processed through established recycling or disposal systems. This initiative not only removes ALDFG from the ocean but also raises awareness among fishers about the impacts of marine litter and promotes responsible waste management practices.

The **FAO's Voluntary Guidelines on the Marking of Fishing Gear** is another critical global initiative addressing ALDFG. These guidelines provide a framework for improving the traceability and accountability of fishing gear, reducing the likelihood of gear abandonment and facilitating recovery efforts. By encouraging member states to adopt gear-marking systems, the guidelines aim to enhance enforcement, promote sustainable practices, and minimize the environmental impacts of lost gear.

Another key initiative is the **Global Ghost Gear Initiative (GGGI)**, spearheaded by the Ocean Conservancy. This alliance of governments, NGOs, and private companies is dedicated to addressing the environmental and economic impacts of ALDFG. GGGI promotes practical solutions such as gear retrieval programs, gear buyback schemes, and the use of biodegradable fishing gear. It also emphasizes policy advocacy and scientific research, providing stakeholders with data-driven insights into the scale and impacts of ghost gear worldwide. GGGI's partnerships with regional organizations and local communities have enhanced its effectiveness in diverse contexts. It also maintains a publicly accessible online database consisting of thousands of ALDFG records submitted by organizations around the world.

The **United Nations Clean Seas Campaign** has emerged as a powerful platform for raising awareness about marine litter and mobilizing action. With over 60 countries participating, the campaign encourages governments to adopt measures such as banning single-use plastics, improving waste management systems, and incentivizing sustainable fishing practices. Clean Seas also partners with industry stakeholders to promote the development and use of eco-friendly materials in fishing gear, addressing pollution at its source.

The **Global Partnership on Marine Litter (GPML)**, under the auspices of the United Nations Environment Programme (UNEP), aims to prevent marine litter by fostering collaboration among governments, international organizations, and research institutions. GPML provides a platform for sharing best practices and innovative solutions, including those addressing fishing-related waste. It also supports the development of regional action plans, integrating global objectives with local contexts to ensure tailored approaches to marine litter management.

The **Econyl® Regeneration System**, developed by Aquafil, is a leading example of how private sector innovation can contribute to global efforts against marine litter. Econyl® focuses on recycling nylon waste, including discarded fishing nets, into high-performance materials for fashion and interior design. This initiative aligns with circular economy principles by creating value from waste and reducing reliance on virgin raw materials. It also highlights the economic potential of integrating waste recovery into supply chains, inspiring similar efforts worldwide.

The **Healthy Seas Initiative**, a collaborative effort between businesses, NGOs, and fishers, focuses on recovering ghost nets and transforming them into sustainable products. Through partnerships with fishing communities, Healthy Seas organizes clean-ups dives to retrieve lost nets from the seafloor and open water. The recovered gear is then sent to recycling facilities, such as Aquafil's Econyl® production system, to create new materials for textiles and consumer goods. Healthy Seas exemplifies the integration of environmental conservation with circular economy principles.

At the regional level, **Regional Fisheries Management Organizations (RFMOs)** have implemented measures to address ALDFG in specific fisheries. For instance, the Western and Central Pacific Fisheries Commission (WCPFC) mandates the reporting and retrieval of lost gear, while the North East Atlantic Fisheries Commission (NEAFC) requires gear marking to improve traceability and accountability. In the Mediterranean and Black Sea, the GFCM, has adopted targeted recommendations to reduce ALDFG, including on gear marking (GFCM/42/2018/11) and gear retrieval and reporting (GFCM/44/2021/14). These organizations play a critical role in aligning fishing practices with sustainability goals, ensuring that ALDFG management is tailored to local ecological and operational contexts.

The **Common Oceans ABNJ Program**, implemented by the FAO, tackles marine litter within the context of the high seas, addressing challenges unique to areas beyond national jurisdiction. This program includes measures to reduce the impacts of ALDFG, such as promoting the use of gear designed to minimize loss and encouraging compliance with international regulations. It also fosters partnerships among governments, RFMOs, and the private sector to enhance the governance of shared marine resources.

Another notable global effort is the **Net-Works™ Program**, a partnership between Interface, Inc. and the Zoological Society of London. This initiative operates in coastal communities in developing countries, engaging local fishers in collecting discarded fishing nets for recycling. The nets are processed into carpet tiles and other high-value products, creating economic opportunities for participants while reducing plastic pollution. Net-Works illustrates how business models can align with environmental and social objectives.

Public-private partnerships have proven to be instrumental in advancing ALDFG initiatives. Collaborations between businesses and conservation organizations, such as the partnership between "Patagonia" and "Bureo", demonstrate how innovative products can emerge from recycling discarded fishing gear. These partnerships create incentives for responsible waste management and raise consumer awareness about the environmental impacts of marine litter.

Technological advancements are increasingly being integrated into global initiatives. Projects such as **Project Seafeather** utilize GPS and sonar technology to locate and recover ghost nets in deep-sea environments. These tools enhance the efficiency of retrieval operations and minimize the risks of further environmental damage. Similarly, digital platforms for gear marking and reporting, supported by initiatives like GloLitter, streamline data collection and improve accountability.

In conclusion, the diversity of initiatives addressing ALDFG worldwide underscores the collective effort to mitigate marine litter and promote sustainable fishing practices. By combining prevention, recovery, recycling, and innovation, these projects offer scalable solutions to a global problem. Continued collaboration among stakeholders, supported by strong policy frameworks and financial investments, will be essential for expanding the reach and impact of these initiatives.

7.2 Existing Projects and initiatives addressing Waste Management from Fishing Vessels in the Mediterranean Sea

Addressing waste management from fishing vessels has become a priority for numerous regional and international initiatives aimed at preserving the Mediterranean's ecological integrity and supporting the sustainability of its fisheries. These projects focus on prevention, recovery, waste infrastructure enhancement, and stakeholder collaboration.

One prominent initiative is the BlueMed Initiative, which emphasizes fostering collaboration among Mediterranean countries to tackle marine litter, including fishing-related waste. BlueMed supports research, innovation, and pilot projects targeting the collection and recycling of ALDFG. Notable among its efforts is the promotion of biodegradable fishing gear to reduce the environmental impact of lost or discarded nets and traps. By encouraging cross-border cooperation, BlueMed has strengthened the capacity of Mediterranean countries to address waste management challenges collectively.

The Fishing for Litter (FFL) program has been widely implemented in the Mediterranean, engaging fishers in retrieving marine litter, including ALDFG, during their routine fishing activities. Participating vessels are equipped with bags to collect litter encountered at sea, which is then offloaded at designated port reception facilities. In addition to cleaning up the marine environment, FFL programs raise awareness among fishers about the impacts of marine litter and encourage responsible waste disposal practices. Countries like Italy, Greece, and Spain have adopted FFL programs, supported by partnerships between fishing communities, NGOs, and local governments.

The MedSeaLitter Project, funded under the Interreg Mediterranean framework, focuses on improving the management of marine litter through monitoring, prevention, and mitigation efforts. The project integrates scientific research with stakeholder engagement, developing tools to monitor ALDFG and assess its ecological impacts. In collaboration with fishing communities, MedSeaLitter has tested strategies for gear recovery and recycling, demonstrating practical approaches to waste management.

The Clean Sea LIFE Project, a European Union-funded initiative, works to combat marine litter in the Mediterranean by mobilizing diverse stakeholders, including fishers, recreational users, and policymakers. A key component of the project is the retrieval of ghost nets from marine protected areas and other vulnerable habitats. Clean Sea LIFE also emphasizes capacity building, providing training for fishers on sustainable practices and the proper disposal of fishing gear. The project's success in engaging local communities has been a model for similar efforts across the region.

Another significant project is the Plastic Busters Initiative, under the aegis of the Union for the Mediterranean. Plastic Busters focuses on reducing plastic pollution, including waste from fishing vessels, through monitoring, prevention, and policy advocacy. It promotes the use of advanced gear marking systems and encourages the adoption of circular economy principles in managing end-of-life fishing gear. Pilot programs under this initiative have demonstrated the feasibility of recycling fishing nets and ropes into consumer products, highlighting the potential for economic opportunities in waste recovery.

The GloLitter Partnerships Project, a global initiative led by the IMO and FAO, has extended its reach to the Mediterranean, working with partner countries to improve waste management from fishing vessels. GloLitter provides technical assistance in developing national action plans, enhancing port reception facilities, and implementing gear-marking systems. By addressing both infrastructure and policy gaps, GloLitter supports the region's efforts to meet international standards and reduce sea-based marine litter.

In Greece, the **Enaleia Project** has gained recognition for its innovative approach to tackling ALDFG. Through its "Mediterranean Clean-Up" program, Enaleia works with local fishers to collect discarded fishing gear and other marine debris. The recovered materials are sorted, cleaned, and sent to recycling facilities, where they are transformed into new products such as textiles and consumer goods. Enaleia's emphasis on education and community engagement has inspired similar initiatives in neighbouring countries.

Spain has been at the forefront of efforts to manage fishing waste, with projects like **EcoALF's Upcycling the Oceans Initiative**. This program collaborates with fishers to retrieve plastic waste from the Mediterranean and repurpose it into high-quality textiles. The initiative demonstrates the economic potential of recycling marine litter while addressing the environmental crisis caused by plastic pollution.

While the Barcelona Convention and its Regional Plan on Marine Litter Management provide a strong policy foundation for addressing marine litter, including from sea-based sources, the General Fisheries Commission for the Mediterranean (GFCM), under the FAO, holds the regional mandate for fisheries management. In this capacity, the GFCM has adopted specific recommendations to reduce ALDFG and supports Contracting Parties through technical assistance and capacity-building efforts. This complementarity ensures that both environmental and fisheries dimensions are addressed in a coordinated manner. These frameworks encourage member states to adopt measures such as enhancing port reception facilities, implementing fishing gear marking systems, and establishing national monitoring programs. They also support knowledge sharing and capacity building to harmonize waste management practices across the region.

Challenges remain in scaling these initiatives, particularly in ensuring adequate funding, infrastructure, and stakeholder engagement. Many smaller ports lack the resources to establish effective waste management systems, and fishers in artisanal or small-scale operations often face financial and technical barriers to compliance. Addressing these gaps requires sustained investment and international cooperation to support the region's efforts to tackle ALDFG.

In conclusion, the Mediterranean Sea has become a focal point for innovative projects and collaborative efforts to address waste management from fishing vessels. Initiatives like BlueMed, Fishing for Litter, and Plastic Busters demonstrate the potential for coordinated regional action to reduce marine litter and promote sustainable fisheries. By integrating scientific research, community engagement, and policy advocacy, these projects provide a blueprint for addressing similar challenges in other regions.

7.3 Initiatives dedicated to Port reception facilities

Port reception facilities (PRFs) have become pivotal in addressing waste management challenges associated with the fishing industry. Numerous initiatives around the world demonstrate how ports, authorities, and stakeholders have implemented PRFs tailored for waste from fishing, including pre-treatment, selection, recycling, and cost considerations. These initiatives not only mitigate environmental harm but also support the development of a circular economy by integrating sustainable practices into the fishing industry's operations. Among the existing initiatives, the following are key, showcasing their operational frameworks, outcomes, and innovations.

GloLitter Partnerships: Promoting Sustainable Waste Management

As for waste from fishing vessels, The GloLitter Partnerships, led by the International Maritime Organization (IMO) and the Food and Agriculture Organization (FAO, and promoting collaboration with developing countries, the project provides technical and financial support for establishing PRFs. A significant component of the initiative involves developing port waste management plans that include waste pre-treatment facilities and mechanisms for selection and recycling. These plans integrate the

MARPOL Convention's guidelines on waste handling and ensure adherence to international environmental standards.

GISIS Port reception Facility Database- (IMO related)

The Internet-based Port Reception Facility Database (PRFD) went live on 1 March 2006, as a module of the IMO Global Integrated Shipping Information System (GISIS). The database provides data on facilities for the reception of all categories of ship-generated waste. The public is allowed free access, following a simple initial registration, to all the information on a view-only basis. Data for reception facilities can be updated only by the respective Member States. The database aimed at improving the rate of reporting alleged on inadequacies of reception facilities so that the problem can be tackled more effectively.

MARELITT Baltic Project: Comprehensive Waste Treatment for Fishing Gear

The MARELITT Baltic project stands out as a transnational effort to tackle the issue of ALDFG. Funded by the EU's INTERREG Baltic Sea Region Program, this initiative incorporated all stages of waste management—from retrieval at sea to recycling at ports. Participating countries, including Estonia, Germany, Poland, and Sweden, have developed a treatment scheme for derelict fishing gear. This involves the pre-treatment of collected gear, such as cleaning and dismantling, followed by recycling trials to convert the materials into new products. The project's approach not only addresses ALDFG but also highlights the economic viability of reusing materials.

Fishing for Litter Schemes

Fishing for Litter programs, implemented in several European countries, encourage fishermen to bring back litter collected during their operations. These schemes are closely linked to PRFs, where waste collected by fishermen is sorted and prepared for recycling. In the UK and the Netherlands, for instance, ports provide facilities for the disposal and pre-treatment of waste, such as sorting plastics for mechanical recycling. This initiative demonstrates how partnerships between fishermen and port authorities can create a seamless waste management system.

Circular Economy and Recycling Efforts

In Norway, the recycling of fishing nets into raw materials for industries like construction and textiles exemplifies the potential of a circular economy. Ports equipped with advanced sorting and pre-treatment facilities ensure that retrieved gear is prepared for mechanical recycling. Similarly, initiatives in Peru and Chile under the Net Positive program focus on converting old fishing nets into nylon products, providing economic incentives for fishermen to deliver their end-of-life gear to PRFs. These examples emphasize the importance of integrating recycling technologies into port operations.

Techno-Economic Feasibility Studies for PRFs

To ensure the economic viability of PRFs, several initiatives have undertaken techno-economic feasibility studies. These studies assess the costs and benefits of establishing waste management systems, including pre-treatment and recycling. The IMO's guidance on conducting such studies highlights strategies for funding PRFs, such as indirect cost recovery systems. These systems distribute costs among all port users, aligning with the "polluter pays" principle and ensuring financial sustainability.

Strengthening Regional Cooperation

Regional collaborations have proven instrumental in enhancing the effectiveness of PRFs. For instance, the Baltic Sea countries, under the Helsinki Commission (HELCOM), have implemented shared guidelines for handling fishing waste. These guidelines promote uniform practices across ports, from pre-treatment protocols to recycling partnerships. Similarly, the European Union's Directive 2019/883 on port reception facilities mandates member states to provide adequate facilities for waste from ships, including fishing vessels. Such initiatives ensure consistency in waste management practices across regions.

Despite their successes, these initiatives face challenges such as limited resources, inconsistent enforcement, and the high costs of advanced recycling technologies. Lessons from these programs highlight the need for stakeholder engagement, robust monitoring systems, and continued innovation in waste treatment processes. For example, the MARELITT Baltic project's use of modular pre-treatment facilities demonstrates how scalability can address capacity constraints at smaller ports. By integrating pre-treatment, recycling, and cost recovery mechanisms, these programs showcase best practices that can be replicated and adapted globally.

8 EXISTING REGULATIONS ON ALDFG AND PORT RECEPTION FACILITIES

The legal frameworks addressing ALDFG and other fishing-related waste are diverse, encompassing international treaties, regional agreements, and national regulations. These frameworks are essential for promoting sustainable fishing practices, reducing marine litter, and ensuring accountability among stakeholders. Each framework contributes specific provisions to mitigate the environmental, economic, and social impacts of ALDFG.

The United Nations Convention on the Law of the Sea (UNCLOS) serves as the foundation for ocean governance, providing the overarching legal framework for managing marine resources and addressing pollution. UNCLOS obliges states to adopt measures to prevent, reduce, and control pollution of the marine environment, including waste from fishing activities. It also encourages cooperation among nations in developing and enforcing regulations for sustainable fishing practices and waste management. While UNCLOS does not specifically address ALDFG, its general provisions establish a basis for national and regional legislation to manage fishing-related waste.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is a key treaty for managing waste from fishing vessels. Annex V of MARPOL explicitly prohibits the discharge of plastics, including synthetic fishing gear, into the sea. It mandates the provision of adequate port reception facilities (PRFs) to collect waste from ships, ensuring that vessels have alternatives to dumping at sea. MARPOL also requires vessel operators to maintain garbage management plans and logbooks to track waste disposal. These provisions form a critical regulatory framework for preventing ALDFG, but challenges remain in enforcing compliance, particularly among small-scale fishers.

The United Nations Environment Programme (UNEP) has advanced the global agenda on marine litter, including ALDFG, through its resolutions and initiatives. UNEP has championed the development of regional action plans, such as the Mediterranean Action Plan and the Black Sea Marine Litter Regional Action Plan, which emphasize prevention, monitoring, and recovery of marine debris, including fishing gear. UNEP's work complements legal frameworks by fostering international cooperation and capacity building for managing ALDFG.

The Convention on Biological Diversity (CBD) provides indirect support for addressing ALDFG through its emphasis on conserving marine biodiversity. Although not explicitly focused on ALDFG, the CBD encourages states to adopt ecosystem-based management approaches that include measures to mitigate ghost fishing and its impact on endangered species. The CBD's recognition of ALDFG's role in biodiversity loss underscores the need for integrated legal and environmental strategies.

The **London Convention and Protocol** complements MARPOL by regulating the dumping of waste at sea. These agreements prohibit the disposal of persistent plastics and synthetic materials, emphasizing the environmental risks associated with such practices. The Protocol adopts a precautionary approach, prohibiting all dumping unless explicitly permitted. Together, the London Convention and Protocol strengthen the global legal framework for preventing ALDFG by addressing the intentional disposal of fishing gear.

The **United Nations Fish Stocks Agreement (UNFSA)** focuses on the conservation of straddling and highly migratory fish stocks, emphasizing sustainable fishing practices. Article 5(f) of the UNFSA calls for measures to minimize the impact of lost or abandoned fishing gear, including the adoption of advanced gear technology and effective fisheries management strategies. By integrating ALDFG mitigation into the broader framework of sustainable fisheries, the UNFSA supports the alignment of environmental and resource management goals.

In the Mediterranean and Black Sea, the General Fisheries Commission for the Mediterranean (GFCM), established under the FAO, holds the regional mandate for the conservation and sustainable use of marine living resources. As the competent RFMO in the region, the GFCM has adopted binding recommendations and resolutions to address ALDFG, including the marking, retrieval, and reporting of fishing gear. These instruments—such as Recommendation GFCM/42/2018/11 on gear marking and Resolution GFCM/44/2021/14 on ALDFG—form a critical part of the legal framework for sustainable fisheries and marine litter reduction in the region. The GFCM also supports Contracting Parties through technical assistance, capacity building, and regional cooperation, reinforcing its role as a key actor in the governance of fishing-related waste.

The **FAO Voluntary Guidelines on the Marking of Fishing Gear** is a critical tool for addressing ALDFG. These guidelines recommend gear-marking systems to improve traceability and accountability, making it easier to identify the owners of lost gear and facilitating retrieval efforts. Although non-binding, these guidelines provide a practical framework for countries to incorporate gear marking into their fisheries regulations, reducing the likelihood of gear abandonment and loss.

At the regional level, the **European Union (EU)** has established comprehensive legislation addressing ALDFG, including the Port Reception Facilities Directive and the Single-Use Plastics Directive. These laws mandate adequate waste reception infrastructure in ports and ban certain disposable plastic products commonly associated with marine litter. The EU also promotes extended producer responsibility schemes, which require fishing gear manufacturers to contribute to the costs of gear collection and recycling, thus creating economic incentives to reduce ALDFG.

Other regional agreements also play a significant role in addressing ALDFG. Regional fisheries management organizations (RFMOs) like the North East Atlantic Fisheries Commission (NEAFC) and the Western and Central Pacific Fisheries Commission (WCPFC) have adopted binding measures to regulate the reporting and retrieval of lost gear, promoting accountability among fishers.

In this context, the GFCM stands out as the RFMO for the Mediterranean and Black Sea with a clear mandate to manage fisheries sustainably and reduce ALDFG. Its legal instruments, including Recommendation GFCM/42/2018/11 and Resolution GFCM/44/2021/14, provide a structured approach to gear marking, retrieval, and reporting. These measures are supported by technical assistance and regional cooperation efforts, particularly aimed at small-scale fisheries. The GFCM's role is essential in aligning fisheries management with marine litter reduction goals in the region.

Finally, national legal frameworks further operationalize these international and regional agreements. Countries such as Norway, the United States, and Australia have adopted specific measures to address ALDFG, including mandatory gear marking, reporting of lost gear, and penalties for deliberate gear disposal. In the United States, the Marine Debris Act supports community-based programs for retrieving ALDFG and recycling fishing gear, while Norway's regulations include stringent controls on lost gear retrieval and incentives for sustainable fishing practices.

The **Barcelona Convention** and its Regional Plan on Marine Litter Management in the Mediterranean provide a comprehensive framework for tackling fishing-related waste in the region. The plan mandates the implementation of measures such as gear marking, port waste management systems, and public awareness campaigns. While a component of the convention (MEDPOL) manages projects and actions on Marine litter, including ALDFGs, another component of the Barcelona Convention, the Regional Mediterranean Centre for Emergency Response to Accidental Marine Pollution (REMPEC) supports Mediterranean states in the ratification, transposition, implementation, and enforcement of international maritime conventions related to the prevention of, preparedness for, and response to ship-generated pollution. It implements projects and initiatives on PRFs, including, directives, information/ training, workshops, and technical reports.

Similarly National legal frameworks operationalize these international and regional agreements, tailoring them to local contexts. Countries such as Norway and the United States have enacted regulations requiring the reporting and recovery of lost gear. In the United States, the Marine Debris Act supports community-based programs for removing and recycling ALDFG, while Norway's fisheries laws mandate the use of gear marking and retrieval equipment. These national efforts demonstrate the importance of localized approaches in implementing global standards.

The legal aspects of ALDFG management encompass a complex interplay of international treaties, regional agreements, and national regulations (Hodgson, 2022). These frameworks provide the foundation for reducing marine litter and promoting sustainable fishing practices, but their effectiveness depends on robust enforcement, capacity building, and stakeholder engagement. Strengthening legal mechanisms and fostering international cooperation will be crucial for addressing the multifaceted challenges posed by ALDFG and achieving long-term sustainability in marine resource management. Challenges in legal enforcement remain a significant barrier to addressing ALDFG. Monitoring and compliance are often hindered by limited resources, particularly in developing countries. Small-scale and artisanal fishers, who operate outside formal regulatory systems, are frequently excluded from these frameworks, creating enforcement gaps. Additionally, the lack of harmonized definitions and reporting standards for ALDFG complicates international collaboration.

9 IDENTIFYING GAPS IN ADRESSING WASTE FROM FISHING VESSELS IN THE MEDITERRANEAN SEA

Waste from fishing vessels, including ALDFG, represents a growing environmental challenge, contributing significantly to marine pollution and threatening marine ecosystems worldwide. However, despite the urgency of the issue, a critical lack of data remains. Exploring the complexity of this issue in the Mediterranean region highlights key areas where data is insufficient or entirely absent (**Table 8**).

Addressing the scientific, technical, environmental, economic, and political aspects, including the ecological impacts on target and non-target species, has become crucial.

Furthermore, this analysis underscores the necessity of localized and regional studies. The discussion extends to waste generated from fishing vessel operations, including microplastics, and the urgent need for improved port reception facilities to manage fishing-related litter efficiently. By addressing these critical knowledge gaps and proposing refined strategies for data collection and ALDFG management, this report will provide a strong foundation for defining recommendations that support the development of targeted interventions, ultimately promoting sustainable fisheries and marine conservation in the Mediterranean.

Table 8. Critical gaps to improve knowledge on waste from fishing vessels in the Mediterranean Sea, and support management measures

Data gap on ALDFG	**Focus on the southern Mediterranean:** Small-scale and artisanal fisheries dominate the fishing landscape in the southern Mediterranean basin. Despite their significance, there is a glaring lack of data on ALDFG originating from these fisheries. Unlike industrial operations, small-scale fisheries often operate in fragmented and informal networks, making data collection challenging. The absence of structured monitoring and reporting systems in many southern Mediterranean countries exacerbates this issue.
	ALDFG categories and differentiation among sub-gear types: Future studies need to more clearly distinguish across sub-gear types, because sub-gears classified under the same overarching gear category may have very different impacts following loss. There is also a lack of quantitative information regarding the amount of ALDFG from the recreational fishing sector, documented as the dominant type of ALDFG present in some water bodies. Overall, research will allow for a more nuanced and informed discussion across fisheries, also helping to sort ALDFG before processing them in Port Reception Facilities.
	Impacts of ALDFG on target and non-target species: Population-scale impacts on both target and non-target resources are largely unknown and understudied. There is almost no information on ALDFG impacts on major fisheries. As well, ALDFG wildlife entanglement is circumstantial and opportunistic, precluding any kind of global assessment of impact. Distinguishing between actively deployed gear and ALDFG as causes of wildlife entanglements is clearly another question to address.
	Need for substantial resources: The collection of comprehensive data on ALDFG requires substantial resources, including financial investment, trained personnel, and technological tools. Many countries in the Mediterranean region face resource constraints that hinder their ability to conduct systematic studies. Furthermore, these regions often prioritize economic survival over environmental management, leaving gaps in policy implementation and enforcement.
	Regional and National Studies: Localized studies are essential to bridge the data gap and provide insights into ALDFG patterns. For instance, the Marine Litter Med project offers a framework for understanding marine litter, including ALDFG, on the seabed. Expanding such initiatives could clarify the extent of the problem and provide a foundation for targeted interventions. National studies, supported by international collaborations, can serve as a catalyst for comprehensive data collection and analysis.
Challenges in resource	**Significant resource requirements:** Research on ALDFG is resource-intensive, requiring advanced equipment, trained personnel, and robust funding. The development of hotspot maps and effective recovery strategies relies on the

allocation and localization methods to locate ALDFG	availability of accurate data, which is often inaccessible due to financial constraints. Resource limitations also hinder the establishment of consistent monitoring systems, particularly in economically disadvantaged areas of the southern Mediterranean.
	Implementation of precise localization methods: Effective localization methods are crucial for identifying ALDFG hotspots and planning recovery efforts. Acoustic technologies and AI are promising tools in this regard, offering the potential for accurate mapping of ALDFG on the seabed. However, these methods are costly and require specialized expertise, which may not be readily available in the southern Mediterranean region. Collaborative efforts involving regional stakeholders and international partners could help overcome these barriers.
Identification of hot spots	**Hotspot mapping for recovery efforts: Hotspot** maps are essential for identifying areas with high concentrations of ALDFG and prioritizing recovery efforts. These maps provide a visual representation of problem areas, enabling targeted interventions that maximize resource efficiency. Without precise hotspot maps, recovery efforts risk being scattered and less effective.
	Development of new methods: Advanced technologies can revolutionize hotspot identification. Efforts could focus on developing eco-friendly fishing gear, improving the design (new materials, degradable plastics, etc.); and low costs retrieval methods (e.g. marking). Acoustic methods, such as sonar and multibeam echo sounders, can detect fishing gear on the seabed, while AI algorithms can analyse data to predict ALDFG accumulation patterns. Integrating these technologies into marine litter assessment and management programs could significantly enhance recovery efforts.
	Regional and national studies: Localized studies are needed to address specific issues related to ALDFG in different parts of the Mediterranean. These studies should focus on identifying hotspots, analysing the types of fishing gear involved, and assessing their environmental impacts. For example, the Marine Litter Med project has highlighted the importance of regional collaboration in addressing marine litter issues, including ALDFG.
	Targeted studies: Local practices which contribute significantly to marine litter must be considered as a priority. Plastic Octopus Traps in the Gulf of Gabes, Fish Aggregating Devices (FADs) in the Tunisian -Sicilian Channel and around *Balearic Islands*, Mussel socks in northern Adriatic are examples of local / regional practices, which contribute significantly to marine litter. Associated ALDFG create environmental hazards for marine life and ecosystems. Detailed studies are needed to understand the scale of these issues and develop strategies for mitigation, such as alternative designs or improved recovery mechanisms. Collaborative efforts between Italy, Tunisia, and other neighbouring countries could facilitate a coordinated response. The lack of reporting on ALDFG from aquaculture prevents conducting comprehensive assessments has become critical, given the growth of aquaculture worldwide.
Litter from fishing vessels operations, maintenance, and abandonment	**Microplastics from fishing vessels:** While the amount of microplastics released by fishing vessels remains very limited in the Mediterranean Sea, a better understanding of mechanisms of microplastics release from fishing vessels according to various antifouling paint characteristics in the Mediterranean basin, including different types, ages, and weathering conditions in diverse situations and scenarios will help to assess risk towards marine species.
	Items on board fishing vessels that pay cause risks: A better understanding *of the* amounts, distribution, composition, and impact of objects and products specifically used on board fishing vessels (e.g. f polystyrene fish boxes, paints, repair scraps,

	etc.) that may pose a risk in terms of their impact on habitats and toxicity to marine species is needed. This will include those risk to species caught during fishing operations, since these litter objects or products potentially affect the quality of fishing products and posing risks to consumers.
	FRP vessels: There is a necessity of enhancing our comprehension of the distribution, degradation, and environmental effects of abandoned FRP vessels. Coordinated activities are urgently needed to capture and track key information on the distribution of abandonment practices. Work underway indicates that there is some potential for global assessments by satellites imagery (spectral/non spectral), to Create inventory of fishing vessels abandoned in the Mediterranean.
A better understanding of harm caused by waste from fishing vessels	**Quantification of ALDFG impact:** Limited and variable data collection methods make it challenging to accurately quantify the ecological and socio-economic impacts of ALDFG. Many interactions with marine life, particularly entanglement, remain unrecorded due to logistical challenges and the lack of standardized methods.
	Understanding microplastics contributions: There is insufficient knowledge about the specific proportion of microplastics originating from ALDFG compared to other sources, as well as their effects on marine ecosystems across trophic levels. This includes the impacts of Paint Particles and FRP Vessels, particularly their toxicity and persistence in marine ecosystems.
	Species-Specific impact data: Information about the full range of species affected by ALDFG, especially less studied taxa like invertebrates, is incomplete. The impact on behaviours, fitness, and reproduction in different species requires further investigations.
	Regional differences in ALDFG effects: The prevalence and types of impacts (e.g., ghost fishing, habitat degradation) vary across regions, but more detailed data is needed to compare and understand these geographic differences.
	Efficacy of mitigation and removal efforts: There is limited evidence about the effectiveness and potential unintended consequences of ALDFG removal methods, including their ecological impact during retrieval operations.
	Pathways for invasive species: The role of ALDFG as a vector for invasive species and pathogens is not fully understood, requiring further studies on how floating debris facilitates the spread of harmful organisms.
Refined strategies for addressing Identified knowledge gaps	**Enhanced monitoring and reporting systems:** Establishing robust monitoring and reporting systems is crucial for addressing the data gap on ALDFG. These systems should be designed to accommodate the unique characteristics of small-scale and artisanal fisheries, ensuring that data collection is both comprehensive and practical. International support and capacity-building initiatives can help overcome resource constraints.
	Adoption of advanced technologies: While investing in advanced technologies can enhance the precision and efficiency of hotspot identification and recovery efforts regional partnerships and knowledge-sharing platforms can facilitate the adoption of these technologies, ensuring that resource-limited countries benefit from their potential.
	Tailored regional strategies: Addressing ALDFG requires strategies tailored to the specific needs and challenges of different regions. Regional studies and consultations with local stakeholders are essential for developing these strategies. Future research should focus on geographic areas for which there is very little to no information, especially in the southern Mediterranean sea were numbers of small-scale fishing vessels and large-scale artisanal fisheries operate, They also must be undertaken in regions where large-scale/industrial fishing vessels deploy large volumes of gear, such as Northern and central Adriatic, The South west part of the

	Northern basin (Spain/ Alboran sea), The Tunisian-Sicilian channel, The South Eastern part of Türkiye and along the coasts of Egypt.
	International collaboration: The transboundary nature of marine litter underscores the need for international collaboration in addressing ALDFG. Initiatives like the Marine Litter Med project provide a valuable platform for sharing knowledge, resources, and best practices. Strengthening such collaborations can enhance the effectiveness of regional and national efforts.
Areas for improvement of port reception facilities	**Understanding the need for PRFs in fishing operations:** Without appropriate reception facilities, waste from fishing vessels often end up in the marine environment. Targeting studies to better define the design of PRFs in fishing harbours will promote a more efficient waste management systems at ports.
	Core components of PRFs as fishing waste: PRFs must be equipped to handle a variety of waste types generated by fishing vessels, including general waste, hazardous materials, and ALDFG. Dedicated facilities should include segregated containers for different waste categories and specialized equipment for hazardous materials. The design of these systems must accommodate the operational realities of fishing ports, ensuring accessibility and ease of use for all stakeholders.
	Pre-treatment and selection: Pre-treatment is a crucial step in the waste management process, ensuring that materials are prepared for recycling or disposal. This includes sorting waste by type, removing contaminants, and compacting or shredding materials to reduce their volume. For ALDFG, additional steps like cleaning and dismantling nets into recyclable components are necessary. Pre-treatment facilities should be integrated into port operations to minimize logistical challenges and enhance efficiency.
	Recycling pathways: Recycling is a cornerstone of sustainable waste management. The guidelines recommend investing in technologies that can process fishing gear and other marine litter into reusable materials. This includes mechanical recycling for plastics, thermal treatments like pyrolysis for mixed materials, and innovative solutions for converting waste into energy. Collaboration with recycling industries and research institutions is essential to optimize these processes.
	Cost recovery mechanisms: Economic sustainability is vital for the long-term operation of PRFs. Cost recovery systems, such as the indirect fee system, ensure that users contribute to the maintenance and operation of facilities without facing direct financial barriers. This approach aligns with the "polluter pays" principle and incentivizes proper waste disposal. Clear and transparent pricing models are recommended to foster stakeholder trust and participation.
	Infrastructure development: The establishment of PRFs requires a thorough assessment of the port's needs, considering factors like the volume and type of waste generated, the size of the fishing fleet, and the port's geographical location. Modular designs allow for scalability, enabling ports to expand their facilities as needs grow. Infrastructure investments should prioritize durability, compliance with environmental standards, and integration with existing waste management systems.
	Coordination: Active participation of fishermen, port authorities, and waste management companies should also be involved in the planning and decision-making processes to ensure the facilities meet their practical needs.

10 CONCLUSIONS

The Mediterranean Sea demands urgent attention to the issue of marine litter, particularly waste generated by fishing activities. The region's semi-enclosed nature, coupled with its role as a hub for tourism, transportation, and fishing, exacerbates the challenges of marine pollution. Waste from fishing vessels, especially ALDFG, poses significant threats to biodiversity and the livelihoods of coastal communities. The durability of fishing materials, while beneficial for operations, translates into long-lasting pollution.

Fishing vessels generate diverse waste types, including plastic gear, grey water, and materials from vessel maintenance. ALDFG, in particular, remains a particularely complex issue, driven by operational losses, gear conflicts, environmental factors, and limited waste management facilities. These issues lead to environmental degradation, socio-economic losses, and risks to marine life. Mediterranean countries increasingly use standardized ALDFG assessment tools aligned with UNEP/MAP Integrated Monitoring and assessment Programmes (IMAP) indicators, EU MSFD descriptor 10 guidance, GESAMP and FAO/ CGFM guidelines, allowing for comparative regional assessments, policy design, and helps support the marine pollution reduction. Nevertheless the gaps across Mediterranean countries complicates efforts to assess the scope of the problem. Advances in monitoring technologies, such as remote imaging and machine learning, offer potential solutions but require further investment and development for large-scale applications. The absence of harmonized waste management regulations across the Mediterranean also hinders the implementation of effective practices. Disparities in infrastructure and enforcement exacerbate the issue, leaving gaps in the handling of waste at ports and on-board vessels. High costs, limited access to advanced tools, and insufficient on-board storage and port reception facilities undermine the effectiveness of existing waste management systems. The reliance on out-dated methods further restrict progress in addressing marine litter.

To tackle marine litter and promote sustainable fisheries, a multi-faceted approach that encompasses prevention, recovery, and innovation is essential.

Prevention begins with better gear design, including the use of biodegradable and traceable materials. Gear marking systems, as promoted by the FAO Voluntary Guidelines and mandated in the Mediterranean through **GFCM Recommendation GFCM/42/2018/11**, enhance traceability and accountability, reducing the likelihood of gear abandonment. Educational programs and awareness campaigns targeting fishers are also essential to foster a culture of environmental stewardship. Strengthening legal frameworks and infrastructure is equally critical. Harmonized regulations under instruments such as MARPOL, the Barcelona Convention, and GFCM Resolution GFCM/44/2021/14 must be fully implemented and enforced. Simultaneously, investment in state-of-the-art port reception facilities (PRFs) is necessary to provide capabilities for pre-treatment, recycling, and efficient waste processing. These facilities, guided by the "polluter pays" principle, can incentivize compliance and generate funding to sustain and improve waste management practices.

Regional cooperation is a cornerstone of effective marine litter management. As the competent regional fisheries management organization, the General Fisheries Commission for the Mediterranean (GFCM) plays a central role in this effort. Through binding recommendations, technical assistance, and capacity-building activities, the GFCM supports Contracting Parties in aligning fisheries management with marine conservation objectives, including the prevention and reduction of marine litter. Collaboration between UNEP/MAP, GFCM, the EU and other regional actors ensures coherence between environmental and fisheries policies, strengthening synergies and fostering integrated approaches. Knowledge sharing and collaboration among Mediterranean countries, facilitated through initiatives like the FishEBM MED project and the Global Ghost Gear Initiative, can help address data gaps and develop targeted mitigation strategies. Moreover, public-private partnerships also play a critical role in driving innovation and mobilizing resources to develop sustainable waste management solutions. By working together, stakeholders can maximize the effectiveness of their efforts and build momentum for change.

Adopting advanced technologies is crucial for modernizing waste management systems. Integrating cutting-edge monitoring tools, such as acoustic imaging, hyperspectral cameras, and machine learning systems, into existing frameworks can significantly enhance data collection and litter detection. Furthermore, exploring cost-effective retrieval methods and recycling technologies can address ALDFG and end-of-life fishing vessels. For example, converting synthetic gear into reusable products offers a practical solution to reduce waste while promoting sustainability.

Finally, promoting community involvement and awareness is vital for achieving long-term success in marine litter management. Initiatives like "Fishing for Litter" highlight the value of engaging local communities in waste recovery efforts. Expanding these programs can foster a sense of responsibility and provide incentives for fishers to actively participate in clean-ups activities. In addition, public awareness campaigns are instrumental in educating citizens about the consequences of marine litter and encouraging sustainable consumption patterns. By involving the community, waste management efforts can achieve broader support and greater effectiveness.

By prioritizing prevention, recovery, and innovation, Mediterranean countries can create a robust framework for sustainable waste management. Key international agreements and regional initiatives must be fully implemented, alongside sustained investment in technology and infrastructure. Ultimately, the sustainability of Mediterranean fisheries is inseparable from the health of its marine ecosystems. Addressing the issue of waste from fishing vessels is not merely an environmental imperative but a socio-economic necessity. Protecting the region’s biodiversity and ensuring the livelihoods of its coastal communities will require concerted action, driven by science, policy, and community engagement. This underscores the urgency of developing comprehensive strategies to mitigate the environmental and economic impacts of marine litter.

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ANNEX 1

Regional assessment on solid waste from fishing vessels

SPA/RAC is pleased to invite you to complete this form, which aims to assess solid waste generated by fishing vessels in the Mediterranean region.

The collected information will contribute to the development of comprehensive guidelines for reducing and managing solid waste discharge from fishing vessels. This initiative is in line with Action 7 of the Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region. It is being carried out as part of the FishEBM Med project, funded by the Global Environment Facility (GEF) and representing a collaborative effort led by the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP). The project is executed by the General Fisheries Commission for the Mediterranean (GFCM) and the Mediterranean Action Plan (MAP) under the Barcelona Convention, through the Specially Protected Areas Regional Activity Centre (SPA/RAC). Completing this questionnaire will only take a few minutes of your time. We sincerely thank you for your valuable collaboration.

1.Name and Surname

[ ]

2.Email Address

[ ]

3.Country

[Malta]

4.Profile

- ○ National institution/ Focal point
- ○ Regional organization
- ○ Scientific institution
- ○ Environmental institution
- ○ Fisheries manager
- ○ Port authority
- ○ Policy maker
- ○ Fisher
- ○ NGO

5.Position

[ ]

6.Fishing area (indicate country/port/area)

7.Where is the fishing area?

- Within national waters (Please indicate distance in NM below)
- Outside national waters (Please indicate distance in NM below)

8.Indicate the distance in nautical miles (NM)

9.How would you assess the occurrence of marine litter from fishing vessels (Derelict fishing gears, Ghost nets, fish boxes, etc..) ?

- Insignificant problem (please specify tendency below)
- Moderate problem (please specify tendency below)
- Serious problem (please specify tendency below)

10.Specify the problem tendency

- Diminishing problem
- No noticeable trend
- Increasing problem

11.Have you observed areas where marine litter from fishing vessels tends to accumulate at sea?

- Yes
- No

12.If yes, list these areas by name/location

13.Which type of marine litter do you observe being lost at sea in your area?

- Derelict/lost fishing gear
- Batteries
- Ropes and lines
- Expanded polystyrene fish boxes
- Shipwrecks / abandoned vessels
- Other (please specify below)

14.If other, please specify

15. Which type of fishing gears do you observe being lost at sea in your area?

- Seines
- Longlines & hooks
- Pots & traps

- Trawls
- Gillnets & similar nets
- Surrounding nets & lift nets
- Other, please specify below

16.If other, please specify

17.Is there a specific collection area for derelict fishing gear at the port?

- Yes
- No

18.Is there any specific infrastructure in place (e.g. containers, bins)?

- Yes
- No

19.If not, are the derelict fishing gear being disposed together with all other types of waste?

- Yes
- No
- Other (please specify below)

20.If other, please specify

21.Are there any measures (regulation, establishment of derelict fishing gears schemes, awareness raising etc.) undertaken to ensure the sustainable management of these in your area or country?

- Yes
- No

22.If yes, please list below these measures

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